Unlocking Potentials of Innovation Systems in Low Resource Settings

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ABSTRACT

This study examined the dynamics, challenges and opportunities of developing innovation systems in low resource settings with a particular focus on Uganda. It applied perspectives of technoscience and concepts of innovation systems, triple helix as university-industry-government relationships, mode 2 knowledge production and situated knowledges in understanding the context, identifying key policy issues and suggesting ways to address them. A mixed methodology combining both quantitative and qualitative methods was used in the study. It involved review of key policy documents, key informant interviews, focus group discussions and meetings with scientists, business leaders in the target organizations and firms, community members as well as observations of production processes in firms. Findings underscore the need for greater interaction and learning among actors in the emerging innovation systems in Uganda and eastern Africa. An opportunity for this to happen may be the growing number of entrepreneurial initiatives at the university and some public research organizations in the country. The entrepreneurial initiatives are driven by scientists, who are enthusiastic about moving their research results and innovations to market. This makes it plausible, in low resource settings like in Uganda, to promote the university working closely with public research organizations and firms as a locus for research and innovation. However, enabling conditions, which foster interaction and learning among actors, should be put in place. First, there is need to formulate specific policies and strategies with clear goals and incentives to promote growth of particular innovation systems. Second, a clear national policy for financing research and innovation is needed, which involves on the one part core funding to universities and research organizations, and on the other, competitive grants for research and innovation. Third, business incubation services should be established and/or supported as places where entrepreneurial scientists and other persons develop and test their business ideas and models. Fourth, there is need for institutional reforms to make administrative processes less bureaucratic, more cost-effective and efficient. The reforms are necessary for example in processes involving procurement and financial management, research project approvals (for ethics and safety), technology assessments, contracting and licensing and other registration services. The findings and conclusions from this study demonstrate that technoscience perspectives and innovation systems approaches can be adapted and used as a framework for identifying and explaining conditions that promote or hamper innovation in low resource settings as well as policy options to address them.

Key words: Cluster, Innovation, Innovation System, Low resource setting, Research, Science, Technology, Technoscience, Triple Helix, Uganda

Dedicated to Beatrice, Jesse, Jason and Jireh

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ACRONYMS

AGT:	Agro Genetics Laboratories Ltd
AIDS:	Acquired Immune Deficiency Syndrome
ASARECA:	Association for Strengthening Agricultural Research in East and Central Africa
AU:	African Union
BIOEARN:	East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development
BST:	Bovine Somatotropin Hormone
BTH:	Blekinge Institute of Technology
CASTAFRICA:	Conference of Ministers responsible for the Application of Science and Technology to Development in Africa
CICS:	Competitiveness and Investment Climate Strategy
CPA:	Africa's Science and Technology Consolidated Plan of Action
DNA:	Deoxyribonucleic Acid
EAC:	East African Community
EACSO:	East African Common Services Organization
EU:	European Union
FaVMU:	Faculty of Veterinary Medicine, Makerere University
FoAMU:	Faculty of Agriculture, Makerere University
FTO:	Freedom to Operate
GDP:	Gross Domestic Product
HIV:	Human Immunodeficiency Virus
ICT:	Information and Communication Technology
IP:	Intellectual Property
IPR:	Intellectual Property Rights
IRCs:	Institutional Review Committees
ISCP:	Innovation Systems and Clusters Programme
JCRC:	Joint Clinical Research Centre
LPA:	Lagos Plan of Action
MAAIF:	Ministry of Agriculture, Animal Industry and Fisheries
MBL:	Med Biotech Laboratories
MFPED:	Ministry of Finance, Planning and Economic Development
MSI:	Millennium Science Initiative
NAADS:	National Agricultural Advisory Services
NARLI:	National Agricultural Research Laboratories Institute
NARO:	National Agricultural Research Organization
NARS:	National Agricultural Research System
NCHE:	National Council for Higher Education
NDP:	National Development Plan
NPA:	National Planning Authority
NRC:	National Research Council
OECD:	Organization for Economic Cooperation and Development

OFAB:	Open Forum for Agricultural Biotechnology
PEAP:	Poverty Eradication Action Plan
PIRT:	Presidential Investors Round Table
R&D:	Research and Development
R4D:	Research for Development
RUFORUM:	Regional Universities Forum
S&T:	Science and Technology
Sida:	Swedish International Development Cooperation Agency
STI:	Science, Technology and Innovation
UIA:	Uganda Investment Authority
UIRI:	Uganda Industrial Research Institute
UNAS:	Uganda National Academy of Sciences
UNCST:	Uganda National Council for Science and Technology
UNDP:	United Nations Development Programme
UNESCO:	United Nations Educational, Scientific and Cultural Organization
UNFPA:	United Nations Population Fund
UNHRO:	Uganda National Health Research Organization
URSB:	Uganda Registration Services Bureau
USAID:	United States Agency for International Development
UVRI:	Uganda Virus Research Institute
WHO:	World Health Organization
WIPO:	World Intellectual Property Organization

PREFACE

This thesis is based on my work experience and research on science and technology policies and innovation systems in Uganda and eastern Africa. I am inspired by the growing commitment in the country and the region to promote research and innovation for economic growth and sustainable development. Research and innovation keep firms at the competitive edge, provide the evidence for decision making, and empower individuals and communities to make informed choices on things that affect their wellbeing. Investing in research and innovation today is providing tomorrow's citizens with tools to create jobs, improve livelihoods and overcome threats such as negative impacts of climate change and resource scarcity. The continuing challenge is to effectively make these investments in low resource settings, which are often tattered with unique cultures and enormous competing needs for basic human and social services. This thesis explores this challenge and possible ways to address it from a technoscience and innovation system perspective.

The thesis comprises three parts. Part I is an introduction to the thesis. The increasing relevance of innovation systems globally and nationally is highlighted in this part. Challenges in promoting research and innovation and strategies to address them through building functional innovation systems in the country and region are also discussed. The thesis' rationale, aims, and key concepts, which guided the study and methods used are described in this part as well. Part II is a compilation of published papers. The papers have been reformatted from their original publication style to suit the requirements of the thesis. The papers address key innovation systems development issues at both macro and micro levels. Paper 1 discusses integration of science, technology and innovation into Uganda's national development planning processes. Paper 2 introduces a framework/model for understanding structure and dynamics of innovation systems, especially in low resource settings. Paper 3 discusses innovation characteristics in Uganda's formal manufacturing firms, particularly in the food and beverages, chemicals and pharmaceuticals subsectors. Paper 4 is about biotechnology development in Uganda, challenges and policy measures required for nurturing its growth. Paper 5 presents a perspective of technological innovation systems on Shea butter enterprise in northern Uganda. Paper 6 discusses enabling conditions and barriers to growth of clusters in Uganda, using bioethanol and fruit processing clusters as case studies. Paper 7 highlights some practical challenges of moving research results and bio-innovations from the laboratory to market in eastern Africa, and suggests policy options to address them. Part III of the thesis is a summary, conclusions and future research. Key policy recommendations are summarized in this part as well. Data for the work presented in this thesis were obtained empirically through interviews and focus group discussions and meetings with scientists, policy makers, development experts, academicians, business managers and communities, as well as observations of relevant firm innovation processes. Secondary data sources were also used such as organizational reports, publications, policy documents and research databases.

PART I

Chapter 1
INTRODUCTION

1.1 Background

Uganda is still among countries in the Low Human Development Index rank category, with life expectancy at birth in the country estimated at 54.5 years of age (UNDP, 2013; WHO, 2012). Majority of Uganda's population derive their livelihood from subsistence farming mostly using labour intensive technologies such as animal traction and the hoe. Of recent, droughts and floods coupled with declining soil fertility, plant pests and diseases are posing threats to farming in several parts of the country. Access to clean drinking water is a challenge especially in urban areas where only 64% of households have piped water (Ministry of Finance Planning and Economic Development (MFPED), 2012a). Households in both urban and rural areas use firewood and charcoal as main sources of energy but these are becoming scarce due to heavy deforestation. Education is free for primary school, secondary school and non-formal modular courses at vocational and technical institutes. However, the large numbers of pupils and students involved overwhelm the capacity of existing infrastructure to provide adequate scholastic requirements.

Overcoming these and other challenges and improving the standard of life generally in the developing world and/or in low resource settings[1] such as in Uganda is possible through economic growth (MFPED, 2012; Barro, 1996). Uganda's economy has been growing at an average rate of five per cent of real gross domestic product (GDP) per annum since 2005 (MFPED, 2012). This growth is attributed mainly to liberalisation of the economy, control of inflation and efforts to reduce regulatory barriers to business. Nevertheless, in order to reach middle income status which the country aspires for as soon as possible, the GDP growth rate should increase to at least seven per cent per annum (MFPED, 2010; MFPED, 2004).

1 Low resource settings in this respect refers to places, usually in a developing country, with inadequate resources (technical, financial, infrastructural, etc.) to accomplish a task as would normally be done in a developed country.

Improving the business environment and ensuring macroeconomic stability can have some gains in the short run. However, they alone are unlikely to deliver the anticipated higher rate of economic growth and improved living standards over time. New growth strategies have to be explored, which, among other things, includes deliberate measures to promote research and innovation[2]. Studies have shown that sustained increases in economic growth and improvement in standard of life in the long run can only be effectively achieved through research and innovation (World Economic Forum, 2010; Cozzens, et al., 2008).

Research is a significant aspect of the innovation process, though it does not necessarily always lead to innovation (Dodgson & Gann, 2010). The Organization for Economic Cooperation and Development (OECD) defines research and experimental development (R&D) broadly as 'comprising creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications'(OECD, 2002). Innovation is much wider than research. It permeates through to users be they individuals or organizations. Rogers (2003) defined innovation as an idea, practice or object that is perceived as new by an individual or other unit of adoption. According to Schumpeter (1934), innovation is the introduction of new goods or new methods of production, the opening of new markets, new sources of raw material supply or new organisation of an industry. Other scholars such as Witt (2002) and Lundvall (2007) simply refer to innovation as 'new combinations'. Therefore, innovations are new ideas or practices or new or improved goods and services introduced in society. Innovations may be radically new, for example, if a malaria vaccine were introduced today. They may also be incremental, for example, an improvement in product quality or when an existing phenomenon in one place is introduced somewhere else, such as introducing disinfection of portable water using ultraviolet light already in use in some parts of the world to local domestic and secondary municipal water treatment; or if a local bank introduces internet banking services already in use elsewhere. New changes or styles in management of a firm or an organization are also an innovation. Innovation is a major mechanism for growth and development. It is usually the output firms strive to get, for instance, new products, which can be material goods or intangible services, and new processes, which can be technological or organizational in nature (Edquist, 2009).

Ideally research and innovation are intended for good, to improve livelihoods, and to equip humanity with tools to overcome future challenges. Therefore, new growth strategies focussing on research, technology and innovation are desirable for human progress. Recent improvements in economic growth and standards of life of countries of the south like South Africa, Brazil and China have been attributed to research, technology dissemination and innovation (UNDP, 2013).

Innovation creates value, and because of this, several countries including advanced ones like USA, Germany, Finland and Sweden and emerging ones like South Africa

[2] Throughout the thesis, the phrase 'research and innovation' is used synonymously with other phrases like 'science, technology and innovation' or 'science and technology'.

and Malaysia to mention a few, are continuously laying new innovation strategies (European Commission, 2011; Day & Muhammad, 2011; Ministry of Education and Ministry of Employment and the Economy, 2009; Department of Science and Technology, 2008). Most developing countries, particularly in Africa, have also started paying closer attention to research and innovation as the key drivers for socio-economic transformation (Juma, 2011; UNESCO, 2010). Some of these countries like Ethiopia, Uganda and Tanzania have added the word 'innovation' to their traditional science and technology policies to emphasise its importance (Federal Republic of Ethiopia, 2012; MFPED, 2009; UNESCO, 2009).

In 2009, Uganda government passed a national science, technology and innovation (STI) policy; and in 2010, identified STI as one of the key strategies for increasing economic growth and sustainable development in its national development plan (NDP) of 2010-2015 (MFPED, 2010) as well as in its national vision 2040 (Government of Uganda, 2013). According to the NDP, 'STI is the lifeblood of sustainable economic progress and prosperity', and 'has a strategic role in accelerating economic growth process by increasing the efficiency and productivity of all sectors in the economy'. In the Uganda Vision 2040, science, technology, engineering and innovation is considered one of the fundamentals, which Uganda should strengthen in order to achieve its transformational goal. These recent policy developments point to an increasing recognition of the vital role research and innovation could play in contributing to economic growth and transformation of Uganda and the region. However, as studies and experiences have shown, policies and strategies by themselves cannot be effective in promoting innovation unless they are designed and implemented in the context and as a critical aspect of an innovation system (Borrás & Edquist, 2013). Innovation systems are open and evolving relationships among diverse groups of actors involved in the production, diffusion and use of knowledge (Lundvall, 2010; Lundvall et al., 2009; Edquist, 2005).

At a regional conference on innovation systems and clusters held in Bagamoyo Tanzania in 2004, participants reached consensus that one way to speed up industrial and economic growth in Africa would be to build innovation systems and develop innovative business clusters (Mwamila et al., 2004). Participants at the conference observed that 'the concept of innovation systems, if properly adapted and situated in the local context, could help overcome limitations in discussions of technology transfer by widening the spectrum to deliberations on generation, mutual flows and regeneration of knowledge'. The same call was re-echoed at the launching of the Pan African Competitiveness Forum in 2008 in Addis Ababa, stressing that poverty reduction and the sustainable development of Africa lies in strengthening innovation and creating innovative business clusters. Muchie and Baskaran (2012) also agree strongly with the notion that taking an innovation systems approach could unlock the economic potential of Africa.

Scholarly work on innovation systems in Africa generally and in Uganda in particular are still few (Lorentzen, 2012; Groenewegen & Steen, 2006). Nonetheless, the few empirical studies generally point to the need for more knowledge on how innovation systems are evolving in developing countries (Diyamett, 2012) and especially in low resource settings such as in Uganda. For example, Szogs, Cummings, and Chaminade (2009) in their investigation of the role intermediate organisations play in building innovation systems in Tanzania and El Salvador, described innovation systems in developing countries as 'systems in construction', characterised by weak institutional frameworks and low levels of interactions among the actors. They observed that linkages between users and producers in the cases studied were not straight forward, and concluded that the non-sophistication of local users did not provide the necessary incentive to innovate. Furthermore, a study by Kibwika, Birungi and Nassuna (2009) focussing on innovations along the value chains of fish, bananas and vegetables in Uganda, concluded that weak interactions among important actors create the most significant bottlenecks to innovation.

Other studies seem to suggest that the building blocks of innovation systems exist in the country. For example, Kiggundu (2006) in a study of innovative behaviour of local fish processing firms responding to a European Union (EU) ban on fish imports from Uganda following new EU sanitary and phytosanitary standards in the late 1990s, concluded that firms are likely to be more innovative where flows of knowledge and interactions are encouraged. Kiggundu specifically found that public agencies played a key part in facilitating the competition and cooperation among fish processors in Uganda by enforcing standards and assisting in quality improvements. The study also revealed that learning by interacting was greater where high technological requirements would be involved. Similarly, in a study comparing the agricultural research systems and biotechnology in Uganda and Ethiopia, Hall and Dijkman (2006) argued that knowledge and skills should also flow among actors in the non-formal sectors who play a critical role in innovation systems of low income countries. Hall and Dijkman's view is that as the innovation systems concept develops further, families of connected but distinct innovation systems such as clusters of organizations producing and using knowledge in ways that are appropriate to specific agendas and goals, technological settings, and competencies should be recognized. This view is supported by Nabudere (2008) who recommended that policy reforms should be in favour of learning as a developmental strategy. Therefore, interactions and learning, historical patterns, flows of knowledge and information across firms and organizations become important considerations when trying to understand how innovation processes occur generally and also in low resource settings (Trojer, 2004).

This thesis builds on this on-going discourse in broadening understanding of innovation systems in low resource settings. It anchors on the 'innovation wave' which appears to be moving across Africa, and on Uganda's quest for new strategies for science, technology and innovation-led growth as the means to improve living standards, and be part of the global innovation enterprise. The thesis in particular examines the innovation systems evolving in Uganda. The premise is that understanding the existence (or lack thereof) of the interactions among firms and other organizations, and the norms and standards which influence such interactions in the local context is necessary for effective and inclusive innovation policy and strategy development.

1.2 Social and Economic Context of Uganda

Uganda connects with South Sudan to the north, Kenya to the east, Tanzania and Rwanda to the south and the Democratic Republic of the Congo to the west. Its total surface area is 241,550.7 Sq.km, with 32% arable land (Uganda Bureau of Statistics, 2012). Being at the equator, Uganda is a centre of biodiversity, which unfortunately is being rapidly degraded by human activities. Uganda's population is estimated at 35.6 million people (UNFPA, 2012), with slightly over 50% under 15 years of age (World Bank, 2010). At an annual growth rate of 3.2%, the population would rise to 90 million by 2050. The population is quite diverse with about 45 ethnic groups and over 32 different languages spoken. English and Swahili are the official and national languages respectively. Over 80% of people in Uganda live in rural areas and engage substantially in subsistence agriculture.

Uganda's major exports are coffee, tea, cotton and tobacco (exported mainly as raw materials). Other non-traditional exports include fish, assorted fruits, essential oils, vegetables, cereals and pulses, animal products and a few minerals. In 2006, oil reserves were discovered in the Albertine Rift in western Uganda. Uganda is also a growing destination for wildlife-based tourism and eco-tourism. The present and future challenge for Uganda is to manage its natural resources sustainably, and to provide employment opportunities for the youthful population. Thus, Uganda's goal is to transform from a largely peasant society to a modern one in a sustainable way (MFPED, 2010); and more specifically to improve its competitiveness to levels associated with middle income countries. Inevitably, this requires scientific and technological interventions and innovations in all sectors of the economy. Both the five-year National Development Plan (NDP) and the Vision 2040 launched in 2010 and 2013 respectively, identifies the promotion of science, technology and innovation as one of the strategies for delivering Uganda's growth agenda (Government of Uganda, 2013).

Uganda's history is punctuated by political and social problems, especially after independence from Britain in 1962. Between 1962 and 1986, the country was mired in a series of political and civil unrest, which destroyed the economic and social fabric and resulted in much suffering and extreme poverty. This was exacerbated by the Lord's Resistance Army led by Joseph Kony and other rebel groups, who continued atrocities in northern and eastern parts of the country displacing millions of people from their homes between 1986 and 2005. Worse still, the country suffered the scourge of HIV/AIDS epidemic, which peaked adult prevalence of 18% in 1992. Aggressive and unified public campaign advocating behavior change together with treatment options reduced the adult HIV prevalence to 6.4% in 2007 (Uganda AIDS Commission, 2007).

Amidst these upheavals, the National Resistance Movement, which took governmental control in 1986 embarked on an economic recovery program and structural adjustments. These efforts led to a stable macro-economic environment, liberalization and peace. Real GDP growth rate averaged 5.3% p.a. between 2001 and 2011 and is projected to grow at an average of 7% p.a. by 2015 (MFPED, 2010). Uganda became the first country to be eligible for and to benefit from the Highly Indebted Poor Countries initiative in 1998, ensuring some US$ 700m (in nominal terms) in debt relief (World Bank, 2011). Poverty rate reduced from 56% in 1992 to 31% in 2006, and is expected to fall below 24% by 2015 (MFEPD, 2010). With this trend continuing, Uganda could meet the Millennium Development Goal target of halving the proportion of the poor by 2015, and could be on course to achieve universal primary education and reduction in maternal and child mortality. However, to maintain this pace of economic development, closer attention must be paid to building the country's innovation systems, which includes deliberate measures to increase investment in research and innovation.

1.3 Research and Innovation Landscape

1.3.1 Institutional Collaboration in Research and Innovation

Public research organizations and universities in Uganda do most of the R&D. A growing number of not-for-profit research organizations, with some form of affiliations to university or public research organizations are also involved, mainly in health and humanities research; for example, the Makerere University-Johns Hopkins University Research Collaboration undertaking HIV/AIDS research, and the Epicentre-Mbarara which is collaborating with Mbarara University of Science and Technology in malaria and tuberculosis research. Private firms undertaking research are very few. The main public research organizations are: National Agricultural Research Organization established in 1992 and later reformed in 2005 (with 14 institutes country wide); the Uganda Industrial Research Institute established in 2002 (was part of the former East African Industrial Research Institute); and the Uganda National Health Research Organization set up in 2011 (with four institutes). Makerere University accounts for the bulk of research done within the university system.

Most of the R&D in universities and public research organizations is undertaken through international collaborations and sponsorship. Maintaining R&D partnerships locally and with universities, firms and other organizations abroad are crucial not only for knowledge transfer but also for building essential links to regional and international research and innovation funding opportunities. However, frameworks to support these collaborations in universities and public research organizations in Uganda are still weak and in some organizations, non-existent (Nabudere, 2008). Enabling institutional policies and frameworks, for example intellectual property or technology or business management policies, are needed in guiding collaborative work of scientists and innovators especially with private sector and international partners. So far among the universities, only Makerere University has an approved university research and innovation including intellectual property policy since 2008. A lot more effort is, therefore, needed to build the capacity of local researchers and organizations not only to design or formulate, but also implement instruments for research and innovation collaboration within country and with partners abroad.

1.3.2 Regulating R&D Conduct

Research in Uganda is regulated both at the organizational and national level. Section 4(d) of the Uganda National Council for Science and Technology (UNCST) Act (Cap 209) designates UNCST as the 'clearing house for information on research and experimental development taking place in scientific institutions, centres and other enterprises and on the potential application of their results'. By this, all persons carrying out research in Uganda are supposed to register their research projects with UNCST.

The process of getting research registered with UNCST starts at the organization where the researcher is affiliated or where the research is to be done. At the organization, scientific committees, biosafety committees, and research ethics committees (RECs) are set up to review the scientific validity, safety and ethics of given studies, respectively. Organizations that do not have these committees usually rely on the committees of those that have. The RECs, for example, review both the science and ethics of research protocols involving humans as research subjects before the protocols are registered with UNCST. The RECs, which include lay persons from the community, ensure that human research subjects are not harmed by research and that rights and wellbeing of the subjects are not compromised for the sake of research (UNCST, 2007). All RECs in Uganda are accredited by UNCST. Studies involving drug or device testing (i.e. a clinical trial) must in addition to REC approval also be certified by the National Drug Authority in respect of a drug to be tested. This applies to research on animals as well, although a separate animal research ethics committee and guidance is yet to be established. For research in wildlife protected areas approval must be obtained from the Uganda Wildlife Authority; and the National Forestry Authority, where applicable, before the study is registered with UNCST.

As part of the registration process, the researcher fills in research application forms obtainable from UNCST website. UNCST evaluates the research application to ensure that research is conducted safely and ethically, and that the researcher has obtained all the relevant approvals, for example, REC or biosafety approval. It is also to control unauthorised collection and transfer of research specimen abroad. At the moment transfer of biological materials (human, plant or animal including microbial specimen) abroad can be allowed for more advanced tests which are not available in the country. Such transfer is on the basis of a negotiated material transfer agreement between the provider and recipient of the material. The other reason for registering research with UNCST is to be able to receive research findings and disseminate these for policy and decision making. This practice of research registration and clearance is also done by National Councils or Commissions for Science and Technology in Kenya and Tanzania (East African Community, 2000).

However, in Uganda, after the research application is registered and approved by UNCST, the latter sends it to the Research Secretariat in the Office of the President. The Research Secretariat advises on the national security implications of the research application. Involvement of the Office of the President in research application registration and clearance is a tradition, which dates back to the early 1970s because of the war and civil unrest in some parts of the country. It has been a security measure to guard against clandestine activities, which could be carried out under the cover of research. At the same time, it was also meant to facilitate access to areas, which were considered insecure, but where research was necessary to be conducted. However, with improved security situation and alternative security measures, the requirement for prior vetting of research applications by the Office of the President should be due for review, considering also that research regulation in Uganda continues to co-evolve with research progress.

Like in any system, the requirement for research application registration by UNCST after the REC and other approvals at the organizational level may have merits and demerits. The positive side could be that it provides a coherent framework for ensuring safety in research and reduces the chances for potential abuses, especially with respect to research involving human subjects and research with hazardous chemical and biological substances or pathogenic agents, which raise dual use concerns. In other words, the national level tier is a quality assurance mechanism, which checks on the quality and conduct of persons at the organizations; and also provides a mechanism or system for coordination and dispute resolution. The negative side could be that it can be time consuming, and expensive if systems do not operate efficiently. This is particularly important because many layers of research approvals naturally cause delays in obtaining research authorizations. Such delays are a disincentive to research progress and a drawback to researchers who may be constrained by time and limited budgets. However, for policy purposes, benefits and burdens of this two-tier system of research application registration should be appropriately weighed; and any interventions designed should aim at making the research regulatory framework more enabling, efficient and cost-effective.

1.3.3 Training of Researchers, Scientists and Technologists

Majority of researchers, scientists and technologists are trained at local universities and tertiary education institutes. A large number of artisans receive their training through apprenticeship. In this respect, programs aimed at imparting local technical skills especially to the youth are an important aspect of the innovation system in Uganda. In 2012, the President of Uganda launched a 'Skilling Uganda' project under the Ministry of Education and Sports (Sanya, 2012). The program aims at reforming the Business, Technical, Vocational Education and Training in Uganda, so that graduates acquire skills not only to make them relevant for the labour market, but also capable of creating their own jobs (Ministry of Education and Sports, 2011).

Graduate training (especially in science and engineering) is mostly done abroad because of few and inadequate facilities at local universities. A UNCST survey of PhD holders in Uganda in 2012 found that 53% of the PhDs were awarded by Ugandan universities, and 47% by foreign universities (UNCST, 2012). Such training programmes are either pursued on full time, where the students spend the whole period of their training in a foreign university, or through a sandwich, where students spend about half of their stay in foreign universities and the other half at their home university. An example of the latter is the Sida-Makerere University Research Cooperation, which has used a sandwich model for over a decade with much success in building research capacity at the local universities in Uganda. With this model, Makerere University registered more than three-fold increase in its research capacity between 2000 and 2008 (Freeman, Johansson, & Thorvaldsson, 2010). The immediate result of this initiative was that Makerere University became a significant local provider of graduate training and a centre of research in Uganda. A number of other universities have since been established. However, only a few have capacity to offer graduate training, which is usually at masters level and mainly in the fields of social sciences, business administration, information sciences and education (Ecuru et al., 2008). So far the National Council for Higher Education (NCHE) in Uganda has recognised five public and 29 private universities (NCHE, 2013). As local universities grow, so also will the number of locally trained PhDs and Masters. However, it is also good to have Ugandan students trained abroad to pick up knew knowledge. Student exchange programmes and research collaborations, which are already happening through various initiatives, including for example, regional training opportunities provided through the Biosciences East and Central Africa facilities at the International Livestock Research Institute in Nairobi, are important platforms, which also contribute to growth of local innovation systems.

1.3.4 Financing Research and Innovation

Financing research and innovation is largely by foreign or international agencies and government of Uganda. In middle and high income countries private sector is the largest funder of research and innovation. However, in Uganda where the private sector is still too weak to make substantial investments in R&D, and the absence of venture capitalists to support commercialization of research results, government bears the biggest responsibility of financing research and innovation. In the past five years, Uganda's R&D performance as a percentage of GDP fluctuated between 0.2% and 0.5%; most of which, were funds from abroad (Barugahara & Lutalo, 2011). This is far below the spending of at least one per cent of GDP on R&D recommended by the African Union (African Union, 2007).

The government has made some effort to finance research and innovation. The efforts, however, have been piecemeal and have not been sustained beyond their first phases. In financial year 2002/03, for example, government announced a national innovation fund and allocated approximately US dollars 0.2 million for innovation projects. This fund was administered by a National Innovation Fund Committee with a secretariat at UNCST. A total of 14 small sized projects were financed through this fund (UNCST, 2007b). No additional financing was provided to continue this initiative.

However, in 2004/05, government announced a presidential support to scientists scheme, this time allocating approximately US dollars 4.8 million to finance commercialization of research products. The scheme is implemented through UNCST. This funding was targeted to eight selected projects, which were of strategic value to the economy. Most of the projects are still on going. Some of them have so far achieved moderate success. Another presidential initiative is support (approximately US dollars 9.5 million over five years) to projects at Makerere University in the areas of engineering and technology, food processing and animal husbandry. Some of the projects are constrained by delays in annual releases of funds and cuts in the budgets over time. As a result, timely execution of the projects becomes a challenge and sometimes investments are lost from experiments started and not properly followed through to completion.

So far the largest public funding support directed exclusively to research and innovation has been the Uganda Millennium Science Initiative (MSI) project co-financed by the government of Uganda (US dollars 3.35 million) and the International Development Association (US dollars 30 million) starting initially from 2006/2007 to 2012/2013. This project was a promising example of competitive research and innovation funding in Uganda. Its development objective was for universities and research organizations to train more and better qualified scientists and engineers, to conduct high quality and relevant research, and for firms to utilize the research and training outputs to increase their profitability, all for the sake of enhancing a science and technology-led economic growth (UNCST, 2007b). Out of the US dollars 30 million, approximately US dollars 23 million were competitive grants awarded for research (46%), undergraduate science and engineering curriculum development (53%) and cooperative projects with private sector (1%) in the fields of engineering and technology (36%), medical and health sciences (28%), agriculture (19%), crosscutting themes (11%) and natural sciences (6%). The research grants were fairly sizeable with up to US dollars 0.8 million for a senior research team, US dollars 0.25 million for a junior research team, and US dollars 50,000 for a cooperative and student internship project with the private sector. Each science and engineering curriculum development project based at a university received up to US dollars 1.25 million for four years. The period of the research grants were three years, and two years for private sector cooperative projects. The rest of the funding was for institutional strengthening of the Uganda Industrial Research Institute (US dollars five million) and UNCST and outreach, policy studies and monitoring and evaluation. The MSI project was implemented by UNCST; grants selection and supervision was done by an independent Technical Committee comprising members from Uganda and abroad. The grants were awarded in 2007 (12 projects), 2008 (15 projects) and 2009 (12 projects) to multidisciplinary teams. Research teams had post-graduate students at Masters (57 students) and PhD (31 students) levels embedded in the projects. The MSI project's overall implementation progress has been satisfactory (Brar, 2013) with significant results realised in research, curriculum development, science outreach and institutional strengthening, but there were no prospects of continuing it beyond the first phase (Nakajubi, 2013; Dickson, 2011). Competitive grants for research and innovation have similarly been piloted by the National Agricultural Research Organization (NARO) since 2006/07 (Anguzu, 2012; NARO, 2010; Flaherty, Kitone, & Beintema, 2010). The competitive grants scheme provides opportunities for registered private agricultural research service providers to access public funds for research on issues which address demand of end users in areas including, crop and livestock productivity enhancement, natural resource management, aquaculture and related cross cutting issues (NARO, 2013). The grants range from USD 50,000 to USD 90,000 for two to three years. This funding is currently through World Bank support. It is important that efforts are made to maintain this scheme and to ensure that the call for proposals is made regularly to support growth of local innovation systems in the agricultural sector.

In general, financing of research and innovation in Uganda has been progressive since 2000, but to consolidate the experiences and achievements so far gained requires collective efforts to build functional innovation systems in the country.

1.3.5 Research and Innovation Policy Framework

Policies for research and innovation can be traced in different sector policies and pieces of legislation, notable among which are the National Industrialization Policy 2008, the National Agricultural Research Act 2005, and the Uganda National Health Research Act 2011. They all stem from the constitutional provision, which obligates the state to promote science and technology. Article XI (ii) commits the State to 'stimulate agricultural, industrial, technological and scientific development by adopting appropriate policies and the enactment of enabling legislation' (Government of Uganda, 1995). This constitutional provision sets the stage for building innovation systems for development in the country.

More specific policies such as the National Science, Technology and Innovation Policy of 2009 and the National Biotechnology and Biosafety Policy of 2008 are intended to provide a coordinated framework for investment in research and innovation. The challenge is to ensure that the policies are backed by clear strategies and adequate capacity is available for their implementation. In this regard, the role of the Parliamentary Committee on Science and Technology established in 2003 becomes extremely important. The Committee is mandated to, inter alia, review, discuss and make recommendations on scientific and technological content of all Bills laid before Parliament and initiate Bills on strategic issues of science and technology for national development. It is also supposed to follow through the budgets allocated for research and innovation. This Committee is well positioned to assist in harmonizing policies so that they collectively address innovation systems challenges and opportunities. Most importantly, the Committee could play a key role in ensuring that policies create enabling conditions for research and innovation progress as per the constitution. It is, therefore, absolutely critical for this Committee to be well versed with the innovation eco-system in the country through access to well-researched information to support their decisions.

1.3.6 Protecting Intellectual Property

The World Intellectual Property Organization (WIPO) defines intellectual property (IP) as 'creations of the mind', which include inventions, literary and artistic works, and symbols, names, images, and designs used in commerce (WIPO, 2013). Some scholars refer to IP as the creative ideas and expressions of persons which have been fixed in some material form (Jacob, Alexander, & Lane, 2004). In day to day living these ideas and expressions are seen in the form of written documents, new songs, new computer programs, new molecules, new machines, new plant varieties, etc. The government can protect these creative works and ideas (i.e. IP) by granting the owners legal rights (otherwise known as IP rights) to prevent anyone else from using the IP for a certain period of time. These rights are normally in two categories: industrial property rights (i.e. patents for inventions, trademarks, industrial designs and geographic indications of source) and copyright (i.e. literary and artistic works). The rights not only reward individual effort, but also encourage creativity and use of the knowledge made public for social and economic development. A scientist who intends to commercialise an innovation must determine that he/she has a 'freedom to operate', i.e. that he/she is not infringing on any of the above rights or has obtained the necessary permissions from the rights holders. Besides IP, there is traditional (or sometimes indigenous) knowledge which is widely recognized in Uganda, particularly as it relates to utilization and conservation of biodiversity by local and indigenous communities. Protection of traditional knowledge requires a separate regime which is an on-going subject of debate in many countries.

Apparently Uganda has all the necessary IP laws except for the plant breeders' rights which are believed should have a separate law. Examples of existing IP laws include the Patents Act, Copyright and Neighbouring Rights Act, and Trademarks Act. The laws do not distinguish ownership of IP between individuals or the organizations they work for, though they provide for joint ownership. Therefore, individual scientists in Uganda can claim sole ownership of IP rights, except in situations where such ownership has been negotiated through a contract with the employer e.g. university, or if the organization's bye laws and policies state otherwise. However, many scientists and innovators in Uganda are not aware of the existing IP laws. Also, universities and research organizations (except Makerere University) do not have internal policies for IP management or where they exist, they are not used or implemented (Kabi et al., 2013).

Uganda lags behind many countries in IP protection. For example, only 39 patents were filed in Uganda since the year 2000 compared with 452 in Kenya and 22,040 in South Africa (WIPO, 2013b). In 2012, UNCST in collaboration with Uganda Registration Services Bureau (URSB) started a monthly IP clinic to create awareness among scientists and small business owners on IP issues. Also, the ministry for trade and industry together with URSB in the ministry for justice and constitutional affairs are making a joint effort to formulate a national IP policy, especially in regards to Uganda's obligations under the World Trade Organization's Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS). It is hoped that the national IP policy will encourage creativity and spur innovation as well as raise more awareness of the value of IP in the innovation process.

However, IP rights and their associated policy and legal regimes are not ends in themselves. It is one thing to protect IP, finding investment in the IP or strategic ways to manage and utilize IP assets, e.g. through licensing or selling the technology, is another. Thus, a successful IP regime depends to a large extent on how the innovation system as a whole is structured and how well the system is functioning (Motari, 2005).

1.3.7 Science Outreach and Public Participation in Science and Technology Decision Making

Joss (1999) describes public participation as 'the engagement in the processes of policy-and decision making not just of the usual professional experts, policy analysts and decision makers, but also a wider spectrum of social actors'. Public participation in decision making on science and technology matters is useful for getting legitimacy of scientific innovations. It is useful because advances in science and technology promise citizens improved standard of life, but at the same time also presents them with uncertainties about the consequences they may have on the environment or the conflicts they may create with society's values, interests and beliefs. Anecdotal evidence suggests that public participation in science and technology decision making is becoming more pronounced in Uganda. The participation, however, in most cases, is top down. That is to say, the responsible agencies initiate policy proposals at the top and then go down to consult with stakeholders. Policy makers in Uganda usually demand evidence of stakeholder consultations on policy proposals they are presented with.

A growing tendency nowadays among public agencies, research organizations and university colleges and departments is to have open days, science weeks or festivals (fairs) at least once a year where they showcase their achievements. For example, since 2007, UNCST has run consecutively an annual National Science Week in September, with activities spread in different regions of the country. The week is planned by an Inter-Agency Committee appointed by UNCST. The committee comprises members from the university, Ministry of Education and Sports, Uganda Industrial Research Institute, Uganda National Academy of Sciences, UNESCO Commission in Uganda and UNCST. The first National Science Week was presided over by the Vice President of Uganda, and since then, the tradition has been to invite the President or at least a Cabinet Minister to officiate at the event. Normally, the week starts with a science walk, followed by a series of events including exhibitions, science school quizzes, student innovation competitions, and public lectures, among others. The aim is to demystify science and technology to the public so that they appreciate the role of science and technology in national development, and also to encourage young people to choose careers in science, mathematics and engineering. Other countries like United Kingdom, South Africa, Australia, Kenya and Tanzania to mention a few have also held annual science weeks.

The media's role is critical, but scientific matters seldom attract much media attention in Uganda. However, the recent debate on a biotechnology and biosafety law seemed to have captured media interest, and awakened the public's interest to be involved (Karugonjo, 2013). The law is part of a process to domestic the Cartagena Protocol on Biosafety, which is an international agreement among state parties to regulate trans-boundary movement of living modified organisms. The law puts in place mechanisms for safe use of genetic engineering technologies and associated products. The debate in the media seemed to be balanced, with sceptics calling for a total ban of genetically engineered organisms, and proponents highlighting the potential benefits of genetic engineering and calling for the law to be passed to facilitate adoption of the technology.

While different public engagement strategies and programmes are being pursued and implemented in Uganda, like the ones mentioned above, they still fall short of being platforms for true public participation in decision making on science and technology matters. So far they have served more as outreach programmes, promoting and popularizing science and technology to the public, perhaps with some minimal feedback, but without formal mechanisms of eliciting public participation or continual engagement in decision making on science and technology matters. More attention has been devoted to developing communication strategies primarily to enhance visibility of an organization or project, than in programmes that actually engage the community or the public in framing the research and innovation agenda of the organization or the country. The closest public engagement effort could be in large clinical trial cohorts in some parts of the country, where community advisory boards have been established to participate along with researchers in decision making on design and implementation of the trials. Uganda's public engagement strategies in science and technology decision making therefore, needs to be evaluated. Lessons can be learned from more mature science and technology public participation structures like the famous Danish Consensus Conferences (Chopyak & Levesque, 2002).

1.4 Business Environment in Uganda

Conducive business environment is crucial for moving research results and innovation to market, although this link is still fuzzy for most scientists and innovators in Uganda. Some notable efforts to improve the business environment in Uganda have been ongoing for quite some time. It follows from Uganda's commitment to promote private sector as the engine for economic growth (MFPED, 2010). A Private Sector Foundation (PSFU) was specifically created in 1995 to be a body through which government supports development of the private sector. Similarly, the Uganda Investment Authority (UIA) was established in 1991 to promote and facilitate private sector investment in Uganda. The UIA hosts a Presidential Investors Round Table (PIRT) which meets regularly. The PIRT is a high level forum established in 2004. It consists of national and international corporate leaders, and is presided over by the President of Uganda. Priorities for PIRT include, among others, agribusiness development, promotion of ICTs, infrastructure development and improving the regulatory environment for business and commerce. Other initiatives include entrepreneurship capacity building for small and medium scale enterprises championed by Enterprise Uganda.

Of recent, attention has turned to improving competitiveness of firms. For example, government's investment and private sector development strategy of 2000 evolved in to a competitiveness and investment climate strategy (CICS) from 2006 to date (MFPED, 2012c). The CICS represents a public-private partnership for enhancing productivity and competitiveness of the private sector, as well as improving the domestic business environment. A related initiative is the innovation systems and clusters programme (ISCP)-now evolving into a Centre for Innovations and Cluster Development. It started around 2003/04 and is coordinated by Makerere University. The ISCP-Uganda is affiliated to the Pan African Competitiveness Forum launched in 2008 in Addis Ababa, Ethiopia. Their mission is to enhance competitiveness by establishing innovative clusters (and supporting innovation systems) through collaborative arrangements between academia, industry and government. These later efforts point to the growing importance and recognition of the role research and innovation potentially plays in Uganda's economic growth and development. However, it is also important for all the actors to understand how the various efforts are synergised and how each party perceives their role and contribution in building innovation systems in the country.

With respect to business financing, there are a growing number of financial institutions closely supervised by the Central Bank, e.g. commercial banks, microfinance institutions, and development finance institutions notably the Uganda Development Bank, as well as securities and capital markets. However, the link between these financial institutions and the research and innovation fraternity especially in the universities and public research organizations is not visible or is less understood. Also, venture capital for investment in new science-based and innovative business enterprises is less developed, although the growing financial markets could pave way for it. It is important for the financial organizations to know their role and contribution as innovation system actors in the country, so as to develop targeted financial products, which spur innovation.

Efforts to improve the business environment in Uganda, especially reduction of cost of doing business and enhancing competiveness are on going, but must be enhanced. In the 2012 Global Ease of Doing Business Index, Uganda ranked 120th globally out of 185 countries and 2nd in east Africa after Rwanda, 9th in sub-Saharan Africa, and 4th among low income countries (World Bank, 2013). According to the Global Competitiveness Index, Uganda is 123rd out of 144 countries, with the areas of lowest competitiveness being in technology readiness, higher education and training and innovation (World Economic Forum, 2013). Improvement of these indices is one of the challenges to be addressed in Uganda's socio-economic development frameworks and policies.

1.5 Research Problem Statement

Uganda is promoting research and innovation as drivers for socio-economic growth and transformation, for example, by reorienting government policies towards value addition (both to goods and services), agro-processing and bio-product development. However, insufficient knowledge of the structure and performance of innovation systems in the country tends to make investment in research and innovation haphazard and difficult. Interactions and learning within and among firms, universities, research organizations, civil society organizations and all other economic agents, which are necessary for innovation to take place in low resource settings such as in Uganda, are less understood. As such policy makers and other actors are ill-equipped to design and implement interventions that effectively support innovation systems development in the country. As a result, well intentioned research and innovation-related programmes and initiatives risk being implemented in isolation, not understanding how each is part of or supports an innovation system. In the end, the value, relevance and impact of the programmes are usually less appreciated and the programmes often struggle to secure longer term support. Examples of these research and innovation related programmes include, but is not limited, to the following:

- Millennium Science Initiative. This programme provided grants for research, innovation and science curriculum development. It was implemented by UNCST and Uganda Industrial Research Institute.
- Presidential Support to Scientists. This programme is for product development and commercialization of near market technologies. It is implemented by MFPED through UNCST. Other presidential initiative projects are implemented at Makerere University.
- Innovation Systems and Clusters Program. This programme is creating innovative business clusters. It is being implemented at Makerere University.
- One Village One Product. This is a cluster related initiative implemented by the Ministry of Trade, Industry and Cooperatives. It is intervening with technology at the sub-county level.
- Competitiveness and Investment Climate Strategy. This is a programme of the MFPED, which is supporting creation of clusters and improving value chains of key agricultural commodities.

Thus, knowledge of innovation systems and how they are evolving in the country would help in guiding decisions on investments in research and innovation by firms, government and development partners in order to achieve social and economic transformation.

1.6 Objectives

1.6.1 Main objective:

To enhance understanding of innovation systems development in low resource settings;

1.6.2 Specific objectives:

The specific objectives (SO) are to:

SO 1: Examine interactions among innovation system actors in a low resource setting;

SO 2: Develop a model and use it to analyse the structure of innovation systems in a low resource setting;

SO 3: Identify enabling conditions and barriers to growth of innovation systems in a low resource setting;

SO 4: Assess the feasibility of applying innovation systems approaches in a low re source setting.

1.7 Research Questions (RQ)

The key research questions are:

RQ 1: How do actors interact and support each other in an evolving innovation system in a low resource setting such as in Uganda?

RQ 2: What could be the enabling conditions and barriers to growth of innovation systems in Uganda?

1.8 Significance

This thesis improves knowledge of innovation systems evolving in low resource settings, the challenges faced and efforts needed to nurture their growth. Such knowledge is useful for developing inclusive innovation policies and/or making implementation of the existing ones more effective. The thesis informs and catalyses on-going discussions and reforms in Uganda's innovation system especially deliberations aimed at strengthening interactions with and improving the learning environment in firms, universities, government agencies and other organizations. The thesis contributes to the body of knowledge on innovation systems in low resource settings, particularly in Africa, where little has so far been done in this field. Finally, other countries in eastern Africa, particularly the East African Community, may find the findings from this study relevant for designing regional innovation policies and strategies.

1.9 Ethical Considerations

No private or personal identifiable information about individuals was asked or recorded during conduct of the studies leading to this thesis, except names and contact addresses. The study was sensitive about and protected confidential business information, in case any was divulged. It avoided disclosure of any potentially derogative information about a firm or organization participating in the study. All interviews and focus group discussions and meetings were conducted with adult male and female employees or affiliates of the organizations or firms or members of the local community who consented verbally to participate in the studies. An individual was free to decline to participate in the interview or stop it altogether or leave the focus group discussion and meeting anytime if he/she felt uncomfortable. Other informational resources used in the preparation of this thesis were those already in the public domain such as published papers, organizational reports, policies and proceedings.

Chapter 2
CONCEPTUAL AND METHODOLOGICAL CONSIDERATIONS

2.1 Conceptual Framework

This thesis is guided by the concepts of innovation systems, Triple Helix as university-industry-government relationships, Mode 2 knowledge production, technoscience and situated knowledges.

2.1.1 Innovation Systems

The concept of innovation systems was introduced in the 1980s and early 1990s by Christopher Freeman, Bengt-Ake Lundvall and Richard Nelson (Lundvall et al., 2002; Freeman, 1995; Nelson, 1995). It refers to the complex web of interactions and relationships among diverse actors in the production, diffusion and use of knowledge (Lundvall et al., 2009; Godin, 2009; Lundvall, 2007). Lundvall (2007) gives a historical account of the evolution of the concept, tracing it back to 19th century scholars such as Friedrich List. List's idea of a national system of political economy is believed to somewhat have reflected the notion of national innovation system, given also that it took into account a wide set of national institutions including those involved in education and training as well as infrastructure such as transport networks (Lundvall, 2007).

Scholars theorize also that the innovation systems concept has its foundation in evolutionary economics attributed mainly to Joseph Schumpeter's early 20th century work on the link between innovation and economic development (Godin, 2008; Witt, 2002). Evolutionary economics unlike the mainstream neoclassical or traditional economics, assumes that economic agents are not perfectly rational but only bounded rational; that is, as Niosi (2010) puts it, 'they expand their knowledge of the world through trial and error' (Niosi, 2010; Freeman, 1995). Such agents form dynamic links and relationships which are non-linear, and which benefits from knowledge accumulation in a variety of ways (Niosi, 2010), a phenomenon which characterizes the innovation systems concept.

Thus the concept of innovation systems has gained wide recognition among scholars and policy makers since then (Balzat & Hanusch, 2004). It has become rhetoric in some instances, while in others it has become an important analytic framework used to understand technological change, and growth of countries (Sharif, 2010). The innovation system approach enables innovative activities to be analyzed in a broader perspective, not only focusing on outputs (innovation), but also on the processes leading to and the multiplicity of actors involved in generating those outputs. These encompass research and development efforts by universities, firms, public policies, learning processes and incentive schemes.

The innovation system approach is based on the understanding that innovation processes are non-linear and involve multidisciplinary groups with common interest in co-evolution processes. A linear model of innovation assumes that innovation follows a straight (linear) path beginning with basic research and discoveries, going on to applied research, followed by product development and finally production and diffusion (commercialisation) of technologies. The linear model was popular in the 1950s and 1960s, and continues to shape science policy decisions in some countries. Godin (2009) argues that the linear model has persisted in time because of its simplicity and the statistical backing it has. These statistics have been collected since the 1960s and are organized into three broad categories of basic research, applied research and development, and technology diffusion. Policy makers and science advocates often use the linear model to argue for and justify funding for science. Also, during the 1960s and 70s, the linear model was characterised by the notion that market needs were the sources of new ideas to drive research and development as well as technological innovations. This thinking gave rise to the concept of 'technology push' and 'market pull' (Fischer, 2001). The linear approach to innovation is criticised for its lack of sufficient feedback mechanisms, which are crucial in the innovation process. In addition, increasing global competitiveness demands shorter product lifecycles, which means that research and development must be fully integrated into the innovation process (Fischer, 2001). Further criticisms attribute the underutilization of research results to gaps in the linear model. These gaps are commonly referred to as 'innovation paradoxes' or 'valley of death' or 'innovation chasm' (Etzkowitz & Goktepe, 2005). Therefore, the realisation that innovation is neither smooth nor linear but rather an iterative and interactive process involving diverse actors in a continuous learning environment, has led to the increasing adoption of the innovation systems concept. That is, recognizing the complex relationships between organizations and institutions; where 'institutions' refers to the 'rules of the game', e.g. policies, laws, behaviours, norms, routines and practices that regulate relationships and interactions between individuals and groups (Niosi, 2010; Edquist & Johnson, 1997).

The innovation systems concept, however, is still evolving. Scholars are debating whether it forms a theory (Lundvall, 2010) or is simply a conceptual framework (Miettinen, 2002). Miettinen (2002) cautions it could potentially cause tensions because of its divergent meanings and uses; but agrees with the underlying notion of innovation systems being interaction and learning within and between actors. Lundvall and colleagues advise that it is better to consider an innovation system as an 'open, evolving and complex system that encompasses relationships within and between organisations, institutions and socio-economic structures which determine the rate and direction of innovation and competence building emanating from processes of science-based and experienced-based learning' (Lundvall et al., 2009). Not only actors and their relationships but also learning is a central feature of an innovation system. Learning is of two types: the first is the science, technology and innovation-the STI mode of learning, and the second is learning through experience i.e. by doing, using and interacting-the DUI-mode (Lundvall, 2010; Niosi, 2010; Jensen et al., 2007). The STI mode of learning refers to a system of codified learning such as is acquired at universities, or through joint research projects and consultancies. This type of learning requires collaboration with knowledge centres like universities and research organizations. The DUI mode is learning through experience by doing, using and interacting with users, or information exchanges among people. Tacit knowledge (Polanyi, 1962) is a critical factor in the DUI mode of learning. Studies have shown that firms that combine both modes of learning are more innovative than those that rely only on one of the two (Fitjar & Rodriguez-Pose, 2013; Lundvall, 2011).

The concept of innovation system is the main guiding framework in this thesis. It also recognizes that innovation processes are localized, and innovation systems may be local, regional, national or even sectoral when a specific technology, product or service is pursued (Niosi, 2010; Lundvall, 2008). Innovation systems are used inclusively to take into account innovation processes in universities, public research organizations, firms, government agencies and local communities where the study was carried out.

2.1.2 Mode 2 Knowledge Production

Mode 2 knowledge production is a way of producing knowledge, quite distinct from the conventional way (Mode 1) where knowledge is created within a disciplinary and primarily isolated cognitive context (Gibbons et al., 1994). In Mode 2, knowledge is produced in the context of application and in an inclusive and participatory manner. The premise of Mode 2 knowledge production is that knowledge is created in broader, trans-disciplinary social and economic contexts. Knowledge production is no longer a monopoly of a single entity or group of professionals, but is widely distributed across sectors and in different groups in society. That is, the production of knowledge is continuously negotiated and interests of various actors and their unique attributes are taken into consideration (Nowotny, Scott, & Gibbons, 2001; Gibbons et al., 1994). The actors include, but are not limited to, universities, research councils, firms, organizations and policy making bodies. Furthermore, in Mode 2, knowledge production is heterogeneous in terms of skills and expertise of people involved, and usually cultural and social sensitiveness are taken into account (Nowotny et al., 2001). The point of convergence between Mode 2 knowledge production and innovation systems approach is that both emphasize interaction and learning among actors as the source of innovation. It means therefore, that network of knowledge flows, particularly from the universities and public research organizations to centres where such knowledge can be transformed into goods and services become essential in the Mode 2 state. The concept of Mode 2 knowledge production is a guiding framework in this thesis, recognizing that in Uganda centres of knowledge are widely distributed. More actors (universities, research organizations, non-governmental organizations, private firms, and individuals) are emerging, all operating in context specific situations where the role and relevance of local communities is increasingly being emphasized in knowledge production.

2.1.3 Triple Helix

Triple Helix as university-industry-government relationships is considered to be the requisite basis for innovation and development in a knowledge based economy (Etzkowitz & Dzisah, 2007). Triple Helix emphasises interaction, cooperation and co-development among the three institutional spheres: university, industry and government, but with the university having an enhanced role to play (Etzkowitz & Leydesdorff, 2000). In a Triple Helix culture, functions of university, industry and government transform in a way that enables each institutional sphere at specific and relevant situations to assume the role of the other (Leydesdorff & Etzkowitz, 2001). It means that mutual overlap of functions, and creation of boundary or bridging institutions is acceptable in the Triple Helix concept frame. The setting up of a technology/ 'business' incubation facility at the School of Food Technology, Nutrition and Bio-engineering at Makerere University with support from government illustrates a Triple Helix culture. More anecdotes point to emergence of Triple Helix relationships in Uganda, and transformations within the individual institutional spheres of university, industry and government beginning to happen (Lating, 2011). For example, in 2008 Makerere University passed an Institutional Research and Innovation Policy, and also transformed the School of Graduate Studies into a Directorate of Research and Graduate Training as a strategy to tap into the university's latent innovative potential, and engage in enterprise development. Triple Helix as university-industry-government collaboration provides room for flexibility of institutional boundaries which is an important aspect of the work presented in this thesis.

Figure 2-1 shows Triple Helix relationships among the institutional spheres in Mode 2 knowledge production (Nowotny et al., 2001). In the figure, knowledge producing entities (K) comprise universities, research organisations, academies of sciences, and other science and technology related agencies (Nowotny et al., 2001). Lundvall (2007) referred to these entities as the 'knowledge infrastructure'. Government (G) includes science and technology policy, legal and regulatory organizations; and industry (I) includes manufacturing and services whether or not for profit.

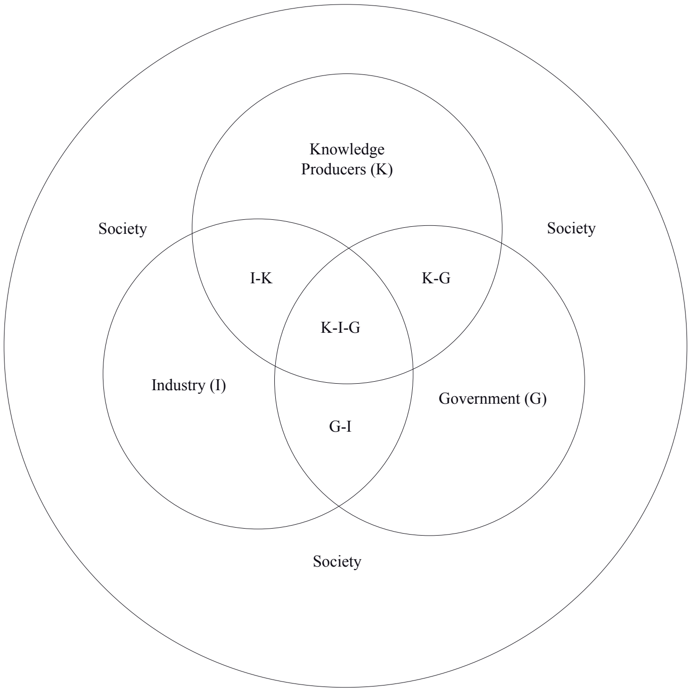

Figure 2-1: Mode 2-Triple Helix constellation of actors

The region K-G, G-I and I-K in Figure 2-1 may: (1) indicate transformations within the institutional spheres so that at specific and relevant situations each can take on the role of the other, and (2) represent intermediary organizations with specific missions, for example, technology brokerage or transfer agents, science advocacy groups, professional societies and so on. The interface K-I-G is a 'Triple Helix convergence' where actors interact, cooperate and co-develop, and promote learning in both formal and informal settings. The relationships at the interface K-I-G are complex, and tend to manifest co-evolution processes. Societal influence is important; every innovative activity must take into account cultural and social sensitivities of the community where its diffusion is taking place.

2.1.4 Technoscience and Situated Knowledges

Science and technology have become increasingly interwoven into everyday life, especially as countries move towards knowledge based economies (Weber, 2006). Technoscience is a concept used to understand the infusion of science and technology and its ramifications on nature, society and human wellbeing. According to Michael (2006), technoscience can be referred to as 'the interwovenness of science and technology, or of knowledge and technique in which technology is indispensable for the production of scientific knowledge'. For example, advances in information and communication technologies are making them crucial tools or artefacts used not only in real life transactions, but also in knowledge production processes. Bensaude-Vincent (2008) argues that Gilbert Hottois, the Philosopher who coined the term 'technoscience' in 1979, explained that technology is embedded in scientific research and is the driving force for scientific inquiry (Bensaude-Vincent et al., 2011). Some scholars (Tala, 2009) favour this unified view, because it embraces both science and technology aspects of contemporary scientific activity.

While technoscience is a relatively recent concept in the discourse of scientific knowledge production, its practice may be old. Klein (2005) traces technoscience to 18th century chemistry, when chemistry of carbon was elucidated and eventually found important uses in the synthetic dye industry. Of recent, several scholars have used technoscientific approaches in their assessments of scientific and technological phenomena. Klitkou, Nygaard, and Meyer, (2007), for example, used technoscience in their exploration of boundary crossing networks in fuel cell and hydrogen technology research and development in Norway. Bain, Ransom, and Worosz (2010), also demonstrated how standards agencies in Michigan State, Chile and South Africa appealed to technoscience values and norms in getting legitimacy for their standards from Michigan fruit growers, South African slaughter house operators and Chilean farmers. A critical aspect of technoscience is its emphasis on interdisciplinarity in the production of knowledge, the embodiment of knowledge, and the localised way in which knowledge is produced (Michael, 2006; Law & Mol, 2001).

In technoscience the production of knowledge is situated, but is transmitted through networks of people, who define its use (Welsh, 2010). This is in agreement with Donna Haraway's view that knowledge is situated and embodied and must of necessity be locatable if rational knowledge claims are to be made (Haraway, 2007). Haraway argues that technologies are ways of life, and it matters from what position one looks at and develops them. To Haraway location, positioning and situating knowledges make claims rational because they are claims on people's lives. Situated knowledges move through networks and connections. Therefore, according to Haraway, 'situated knowledges are about communities, not about isolated individuals'. Lating (2011), based on his experience with trans-disciplinary research in Uganda, also emphasises the importance of situating oneself in the context of the problem and the context of application and implication of the research findings. Therefore, technoscience and situated knowledges are necessary as concepts to emphasize the context, in which innovation processes occur and where the actors have to understand their responsibility for its diffusion and impacts on real life situations in Uganda.

2.2 Analytical Framework

The basic analytical framework represented in Figure 2-2 is derived from the above concepts. The relationship between actors is defined by the institutional framework (i.e. norms and standards) in a given social and cultural context taking into consideration the political and economic environment. Actors could be individuals, firms or organizations regardless of their disciplinary orientation. Institutions are norms, standards, habits, rules, etc. which govern the relationship between actors (Niosi, 2010;

Oyelaran-Oyeyinka, 2006; Edquist, 2005). People develop norms and standards in a given social and cultural context. These in turn shape the way they relate with each other. The prevailing political and economic situation usually exerts significant influence on the practice of science, technology and innovation. These relate to the political agenda of the country, and priorities for investment in knowledge production, technology dissemination and innovation competence building. Social and cultural issues include the local belief system and practices which may shape people's perceptions about a particular innovation, technology or product (Sismondo, 2004).

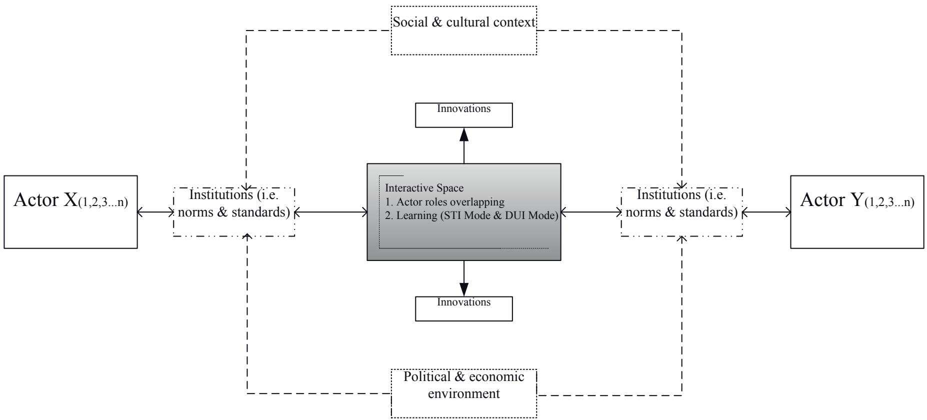

Figure 2-2: Analytical framework.

All these phenomena determine the nature of the interactive space in Figure 2-2. The interactive space is characterised by overlapping roles of actors (Triple Helix concept) and by learning as actors interact (innovation systems concept). When conditions are enabling, interactions occur and the outcome is innovations to increase productivity and profitability of firms or to meet critical needs of a community or society.

In order to allow for a more systematic analysis of sectoral innovation systems, specific technological innovation systems (TIS) scheme of analysis incorporating the analytical framework represented in Figure 2 was adopted. TIS is a variant of innovation systems elucidated by scholars such as Bergek et al., (2008a) and Jacobsson and Bergek (2011). The scheme enables a systematic analysis of key processes (otherwise known as functions) which directly influence the development, diffusion and use of new technologies (Bergek et al., 2008a). These key processes (or functions) are described as follows:

a. Knowledge development and diffusion: breadth and depth of scientific, traditional and local knowledge of a technology or product in question, including research and knowledge of markets and distribution systems;

b. Influence on the direction of search: way in which the system is directed in its development, either through strong overarching industry or political visions, policies, strategies and incentives;

c. Entrepreneurial experimentation: development and testing of market niches and commercialization or dissemination of the technology or product;

d. Market formation: trends in the development of the market, type of the market (nursing, bridging, mature), potential size of the market, and what is generally driving formation of the market for the technology or product in question;

e. Legitimation: public and social acceptance as well as desirability of the technology or product by actors;

f. Resource mobilisation: resources that are available, e.g. financial, human, and other complimentary products or services;

g. Development of positive externalities: external economies brought about by performance of the above functions, including political support, emergence of advocacy coalitions and interest groups.

TIS can be applied sectorally, where a specific technology or product is involved, e.g. in this thesis, the bioethanol and fruit processing clusters were regarded as specific product TISs; while crop improvement technologies (micro-propagation techniques) were considered as specific technology based TIS.

2.3 Empirical Methods

2.3.1 Overall Context

A pragmatic worldview point was adopted for the research work leading to this thesis because of the complex and evolving nature of transformations and relationships in an innovation system. Pragmatism as a worldview emphasizes the practice of understanding the research problem, and working progressively towards identifying possible solutions (Creswell, 2009). This view offered flexibility to apply a variety of qualitative and quantitative methods to understand actors and how they relate in the production, diffusion and use of knowledge.

2.3.2 Study Population

The study population comprised firms and other organizations that were involved in or were expected to play a significant role in research and innovation processes in Uganda and in eastern Africa. These were broadly categorised as: knowledge producing and associated organizations such as universities and research organizations; knowledge users such as industry comprising largely of manufacturing firms (mainly in the bio-resource sector); government organs responsible for policy, financing, standards and regulations; and intermediary organizations such as professional societies and business associations. Non-governmental organizations and civil society organizations working broadly on research and innovation related matters were also involved.

2.3.3 Study Design

The two main design approaches used were multiple case design and cross-sectional survey design (Yin, 2009; De Vaus, 2005). The multiple case design approach was chosen to enable a more exhaustive contextual analysis of sectoral (technology/product) innovation systems chosen as cases. It also enabled use of a variety of methods (Yin, 2009). The cases were studied sequentially, with embedded units of analysis.

A cross-sectional survey was designed to characterize innovation in formal manufacturing firms in the subsectors of food and beverages, chemicals and pharmaceuticals.

2.3.4 Methods of Data Collection

A mixed methodology was used, which combined both quantitative and qualitative approaches in the study (Creswell, 2009; Johnson & Onwuegbuzie, 2004). A mixed method was preferred because of the diversity of actors, and the context-specific nature of innovation systems. The first part of the work involved review of key policy documents. These documents included for example, science, technology and innovation policies, reports of organizations, comprehensive national development frameworks, laws and regulations, research databases in Uganda, and journal articles, papers and related work on innovation systems globally, regionally and nationally. Some of the documents like organizational reports and government policies were solicited from the responsible agencies, or located from those agencies' libraries. Some of them were sourced online from web pages of the agencies. These documents were read. Review notes were made and summarized into key points and issues.

The second part involved semi-structured open ended key informant interviews with scientists, business leaders and administrators in the target organizations and firms visited. Focus group discussions and meetings were also held. Each focus group had eight to 12 participants. Manufacturing processes were observed in firms. Each process was explained by production managers who also addressed all questions put to them. Interviews were recorded on scripts and pictures were taken where relevant. These were later summarized, analysed and discussed in the write up of the papers.

The third part involved a survey of firms in the subsectors of food and beverages, chemicals and pharmaceuticals. The survey was done through questionnaires, which were both investigator-administered and self-administered. The questionnaires were coded and data entered using a form created in Epidata software version 3.1. The data was then transferred to and analysed using SPSS statistics 17 computer software.

PART II

Chapter 3
PAPERS

3.1 Introduction to Papers

This thesis is composed of papers published or in the process of being published in peer reviewed journals and conference proceedings. The papers are reformatted to suit the requirements of the thesis. Below is an introduction to the papers.

Paper 1:

Ecuru, J., Lating, O. P., Ziraba, N.Y., and Trojer, L. (2011). Integrating science, technology and innovation in national development planning process: the case of Uganda. *In proceedings of the 2nd International Conference on Advances in Engineering and Technology, pp 235-241, January 30th – February 1st, 2011, Entebbe- Uganda: ISBN: 978-9970-214-00-7*

This paper analyses how science, technology and innovation is (or is not) integrated in the national development planning process of Uganda. Government's commitment to use science, technology and innovation as a driver for economic growth and sustainable development is normally expressed in its integration of the latter into the national development planning process. The paper acknowledges that science, technology and innovation should be an integral part of the national planning framework in order to benefit from public support and funding.

Paper 2:

Ecuru, J., Trojer, L., Ziraba, N.Y., and Lating, O. P. (2012). Structure and dynamics of Uganda's technological innovation system. *African Journal of Science, Technology, Innovation and Development, Vol 4, No. 4. 2012.*

This paper introduces a framework or model for understanding the structure and dynamics of innovation systems, especially in low resources settings. The framework is used to explain the structure of Uganda's innovation system and its performance. The paper also identifies weaknesses in the system and suggests policy options.

Paper 3:

Ecuru, J., Lating, O. P., and Trojer, L. (2012). Innovation characteristics of formal manufacturing firms in Uganda. *Accepted for publication as a chapter in the Africalics Book on Innovation for African Development: Structures, Systems and Distribution, 2013.*

This paper looks at innovation characteristics of formal manufacturing firms in Uganda, particularly in the food and beverages, chemicals and pharmaceuticals subsectors. It points out the sources of firm innovations, and weaknesses in the innovation system as a whole. Policy options to be considered are suggested.

Paper 4:

Ecuru, J., and Naluyima, H. (2010). Biotechnology developments in Uganda and associated challenges. *African Crop Science Journal Vol. 18, No. 4, pp. 133 – 139; ISSN 1021-9730/2010.*

This paper specifically looks at the growth of modern biotechnology as an enterprise in Uganda, highlighting its application as a tool in crop, fish and livestock improvement, value addition, waste management, and in medicine. The continuing growth of modern biotechnology or more broadly, biosciences as an enterprise in Uganda depends on the support given to science and technology generally.

Paper 5:

Ecuru, J., and Lating, P. O. (2013). A technological innovation systems perspective on the Shea butter enterprise in Uganda. *International Journal of Technoscience Studies, Vol. 1, No. 1, 2013.*

This paper presents a technological innovation systems perspective on the Shea butter enterprise in northern Uganda. It specifically identifies and discusses opportunities for developing a Shea butter cluster or innovation system in the region.

Paper 6:

Ecuru, J., Trojer, L., Lating, P. O. and Ziraba, Y.N. (2013). Cluster development in low resource settings: The case of bioethanol and fruit processing clusters in Uganda. *In Proceedings of the 11th GLOBELICS Conference on Entrepreneurship, Innovation and Economic Development in the Era of Globalization 11th –13th September 2013, Ankara, Turkey (and submitted to the Journal of Entrepreneurship and Innovation Management).*

This paper uses a technoscientific approach incorporating a specific technological innovation systems analytic framework to highlight enabling conditions and barriers to the growth of clusters in Uganda; specifically the bioethanol and fruit processing clusters in Jinja and Luwero districts in Uganda. The paper demonstrates the feasibility of applying technoscientific and innovation system perspectives to cluster development in low resource settings.

Paper 7:

Ecuru, J., Virgin, I., Omari, J., Chuwa, P., Teklehaimanot, H., Alemu, A., Komen, J., Nyange, N., Ozor, N., Opati, L., Karembu, M., & Gasingirwa, C. (2013). Moving bio-innovations from laboratory to market: comparing performance of four bio-innovate technological clusters. *In Proceedings of the 1st Bio-Innovate Regional Scientific Conference 25-28 February 2013, Addis Ababa, Ethiopia.*

This paper highlights the challenges of moving bio-innovations from the laboratory to market in eastern Africa. It makes some policy recommendations, which are specific to the projects studied, but also relevant nationally.

3.2. Paper 1

Integrating Science, Technology and Innovation in the National Development Planning Process: The Case of Uganda

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ABSTRACT

In order to ensure that science, technology and innovation contributes to economic growth and social wellbeing, it must be integrated in the national development planning process. Over the years, the integration of science, technology and innovation in Uganda's national development planning has been implicit. Intentions to use science, technology and innovation as the vehicle for economic growth were evident in the country's comprehensive development framework such as the Poverty Eradication Action Plan (1997/98 – 2008/09) and the National Development Plan (2010/11-2014/15). However, strategies of how to use it to bring about the desired outcomes of economic growth were lacking. The designation of science, technology and innovation in the National Development Plan of Uganda as a sector that provides institutional and infrastructural support to the production of goods and services demonstrates that integration of science, technology and innovation in development planning is possible through endogenous efforts. However, such inclusion of science, technology and innovation in the Plan cannot be an end in itself; rather it is a process of making science, technology and innovation and integral part of national development. This means that the science, technology and innovation provisions of the National Development Plan ought to be implemented in the context of the national innovation system.

Key words: Innovation, Innovation System, Science, Technology, Uganda

INTRODUCTION

Science, technology and innovation (STI) plays a critical role in enhancing economic growth and contributing to national development. It is the means by which new products and services are developed or improved and brought to market. Ideally, these new or value added products and services are intended for improvement of the standard of life. Economically they create new market opportunities, attract better prices and provide employment.

The importance of STI in economic growth and development of low income countries generally and of Uganda in particular has been echoed since the 1960s (East African Community (EAC), 2000). After independence in 1962, the country embarked on nation building with industrialization being at the centre of its development agenda. Although STI was expected to play a key role in the industrialization process, it did not feature vividly in the development plans of the time. There was lack of clarity on how to promote STI for national development. This led some scholars to believe that STI was often given low priority in the development planning process (Senghor, 2000).

Only recently has STI been given more prominence in Uganda's National Development Plan 2010/11 – 2014/15. The NDP stipulates Uganda's medium term strategic direction and development priorities, focusing on growth, employment and socio-economic transformation for prosperity (MFPED, 2010). The plan recognizes STI as a sector that provides institutional and infrastructural support to the production of goods and services. The promotion of STI is identified as one of the strategic objectives for achieving the goals of the NDP. Previously, intentions to use STI as the vehicle for economic growth were evident in the country's comprehensive development framework, which was known as the Poverty Eradication Action Plan (MFPED, 2001). The Poverty Eradication Action Plan (PEAP) was a three-year planning framework for government. Programs and projects not aligned to the PEAP would not be prioritized to receive budgetary support. STI was not explicitly mentioned in the PEAP. The challenge, therefore, was to make STI projects PEAP compliant in order to qualify for public funding.

Thus, the development planning process in Uganda since independence until recently only implicitly considered STI. However, a clear strategy of how to translate the intentions to use STI for development into actions with tangible results was generally lacking. This challenge continues to date even with the deliberate inclusion of STI in the NDP. This paper examines the process of integrating STI in Uganda's national development planning process.

METHOD

The paper is based on a retrospective review of literature on STI in Uganda. A desk review of key STI documents was done. The focus was on the national development frameworks, for example, the National STI Policy (2009); National Industrialization Policy 2008; Poverty Eradication Action Plan 1997, 2001, and 2004; the National Development Plan 2010/11 – 2014/15. Other historical documents pertaining to Uganda's economic development since independence were also reviewed; as well as reports of STI regional and international meetings. The documents were read and summarized.

RESULTS AND DISCUSSION

Science, Technology and Innovation (STI) taken together may *mean a dynamic process involving discovery and generation of new knowledge and the application of knowledge to develop new and/or improve goods and services.* STI is not an end in itself; rather it is the means by which new products and new processes are developed and brought to market. The process of integrating STI in Uganda's national development planning could be looked at from two dimensions: the exogenous and endogenous dimensions.

a) The Exogenous Dimension

Prior to Uganda's independence, STI was an integral part of the central government, which was the East African Common Services Organization (EACSO) with headquarters in Nairobi, Kenya (EAC, 2000). The three countries of Kenya, Uganda and Tanzania first cooperated in matters of STI through the EACSO. The latter body later became the East African Community. With this arrangement STI appeared to be quite well organized. However, STI was focused more on research aimed at improving productivity of cash crops such as cotton and coffee; and tackling tropical diseases such as malaria and trypanosomiasis (EAC, 2000).

This trend continued even after independence in 1962 through to the 1980s. Development planning during this period hardly incorporated STI. However, there was a growing global effort to help developing countries use STI as a tool for development (United Nations Educational Scientific and Cultural Organization (UNESCO), 1987). Several African countries in the 1960s and 1970s established national research councils as coordination mechanisms for scientific research and development. In Uganda, a National Research Council was set up in 1970 to guide and coordinate research efforts (Uganda National Council for Science and Technology (UNCST), 2001). The predominant view at the time seemed to be that industrialization was preceded by research, then experimental development and later production and commercialization of products. This linear view of STI has been criticized because it fails to recognize other factors necessary in the innovation process (Godin, 2006). A systems approach to STI seems to be the more favoured view currently (Balzat & Hanusch, 2004). A systems approach recognizes the contribution of several actors in an interactive learning relationship, and the factors which influence such a relationship (Lundvall, 2007; Oyelaran-Oyeyinka, 2006; Edquist & Johnson, 1997). Innovation is believed to be an outcome of these complex interactions between diverse actors (Lam & Lundvall, 2007).

Most of all the drive to integrate STI into national development planning was initiated by continental wide efforts notably by UNESCO supported Conferences of Ministers responsible for the Application of Science and Technology in Development in Africa I and II (CASTAFRICA I and II) in 1974 and 1987 respectively; and the Lagos Plan of Action (LPA) in 1980 (UNESCO, 1987; African Union, 1980). For UNESCO, rapid scientific and technological progress could only be achieved through the indigenous efforts of developing countries. This view became popular among developing countries because they found it consistent with their aspirations to liberate themselves from colonialism (Mullin, 1987). Consequently, in 1980 African leaders met in Lagos Nigeria and developed a masterpiece LPA. The LPA provided that each country should establish a center or body to "help the country in determining the origins and effects of alleviating the technological dependence and in approaching technological self-reliance by striking a socio-economically favoruable balance between foreign inputs and those inputs that are generated by the indigenous science and technology system and utilized by the national sectors of production and services". Such a centre was to be entrusted with the mandate for national science and technology policies and coordination of all national research and development programmes. This centre in Uganda became in 1990, the Uganda National Council for Science and Technology (UNCST). The UNCST replaced the National Research Council. The ideals of the LPA were for member countries to attain self-sufficiency by becoming technologically independent. The LPA specifically called for member countries to develop short, medium and long term integrated development plans, with science and technology as an integral part. It also called for member states to spend at least 1% of their gross domestic product (GDP) on developing scientific and technological capabilities.

More recently, the Africa's Science and Technology Consolidated Plan of Action (CPA), 2005 prepared by the African Union/New Partnership for Africa's Development became an important regional framework for harmonization of STI development (African Union, 2005). The CPA evolved from a series of continental meetings. It is an instrument to implement the decisions of the African Ministerial Conference on Science and Technology that was held in Johannesburg in 2003. It is built on three pillars: capacity building, knowledge production and technological innovation; emphasizing the development of Africa through a system of research and innovation. The CPA lays down specific flagship programmes and projects including biodiversity, biotechnology and indigenous knowledge; energy, water and desertification; material sciences, manufacturing, laser and postharvest technologies; information and communication technologies and space science; as well as programmes to improve STI policy mechanisms. Implementation of CPA programmes is through centres of excellence; but requires determined and coherent actions by all member states. Undoubtedly, the CPA may have influenced STI planning in Uganda, but the extent of this influence is yet unknown.

These exogenous influences have to some extent shaped the process of integrating STI in the national development process of Uganda. Specifically, they helped to raise awareness among policy makers of the importance of STI in economic growth and development. Despite the efforts, however, regional or continental STI initiatives have been poorly domesticated in Uganda. There is often little room for consultations on these regional initiatives within country, and collective involvement of local actors in the STI system has remained weak. As a result, there is seldom sufficient local ownership for programmes proposed by the regional or continental wide initiatives.

b) The Endogenous Dimension

Endogenously the integration of STI in Uganda's national development planning could have started in the 1990s. During the 1970s and early 1980s, development planning was interrupted by political instability and civil unrest; and further by the structural adjustment programmes of the 1980s and the early 1990s (MFPED, 2010). Between 1986 and 1997 government implemented an economic recovery program aimed at stabilizing the economy and creating a conducive environment for rapid economic growth. These included among others interest rate reforms and fiscal measures to reduce Uganda's budget deficit, liberalization of trade policies and revitalization of the private sector (Kreimer et al., 2000). From 1997 to 2008 development planning was guided by the PEAP. Significant reforms of the public sector happened during this period including the creation of dedicated research and development organizations such as the National Agricultural Research Organization and the Uganda Industrial Research Institute. Government line ministries assumed a policy and regulatory function, leaving research to academic (universities) and research organizations.

It is at this stage that traces of STI integration into national development planning started to emerge. Though not explicitly stated, the need for STI was implied in most of the PEAP actions particularly those meant to increase ability of the poor to raise their incomes such as modernizing agriculture; as well as in actions to improve the quality of life of the poor, for example, in combating HIV, developing more efficient energy systems, designs for improved housing, and improving primary and secondary education (MFPED, 2004; MFPED, 2001). The PEAP was Uganda's comprehensive development framework from 1997 to 2008/09. It was government's three-yearly planning document. All government expenditure had to be aligned to the PEAP. All the PEAPs, PEAP 1997, 2001 and 2004, had no specific actions to promote STI. But they all recognized the need for STI in some of the actions such as those aforementioned. It may have been possible to articulate STI within the context of the PEAP, but such a strategy would not be sufficient mechanism to promote STI primarily because results from STI are usually realized in the long term, though there could also be some short term outputs. PEAP neither provided a clear mechanism of how to use nor invest in STI to bring about the desired outcomes of economic growth. As such it appeared as if STI had been given low priority and no status in the planning process despite its potential central role in enhancing economic growth.

The PEAP was replaced by the five-year National Development Plan (NDP) starting 2010. The plan is the first of six five–year development plans intended to transform Uganda from a peasant society to a middle income country. This time, STI has been included in the NDP as a sector that provides institutional and infrastructural support to the production of goods and services. It is the first time STI has been explicitly recognized in the national development planning process of Uganda. Unlike in the 1960s, 70s and 80s where exogenous influences shaped STI planning, the integration of STI into NDP was an outcome of endogenous efforts. The planning for STI within the NDP was done in a participatory manner involving a diverse group of actors. The success in according STI a sector status in the NDP demonstrates that home grown efforts in STI can be harnessed.

However, designation of STI as a sector within the NDP is not an end itself. It is a learning process of systematically integrating STI in national development planning. As the process evolves, it will be important to guard against the likely danger of promoting STI in isolation and the risk of backsliding to the linear view of STI of the 1960s to 80s. Implementation of the STI provisions of the NDP ought to be undertaken within the context of the national innovation system. Innovation system here refers to the complex web of interactions and relationships among diverse actors (Lam & Lundvall, 2007). It will be essential not only to focus on the expected outputs of the STI in the NDP, but also pay close attention to the multiplicity of actors involved in

STI, how they relate and what policies, laws, behaviours, norms, routines and practices influence their interactions.

Political, cultural, social and behavioural factors notwithstanding, it may be worthwhile to consider the following pillars in support of the process of integrating STI in the development planning process of Uganda:

Human capital: Uganda's human capital base for STI, that is, the pool of knowledgeable, competent and skilled people, is still small. For example, active researchers in all fields were less than 2,000 in 2008 (Ecuru et al., 2008). Increasing the human capital potential depends on the strength of the education system. Uganda's education system is quite well developed and positioned to produce the necessary human capital. However, challenges still exist of improving science and mathematics education as well as improving business and vocational education. Reforms such as universal primary education and universal secondary education and emphasis on science careers at the tertiary level, may increase the supply of scientists; but reforms are also necessary to improve the quality of education.

Governance: Governance, that is, organizing scientists to produce involves formulating policies, issuing guidelines, developing legislation, preparing strategies and plans for STI. Early on in 1990, it was proposed to have an explicit national policy on all fields of science and technology. A National Science and Technology Policy was first proposed at a National Workshop in 1991 and approved by Cabinet in 2009. The policy provides an overarching framework for investment, coordination and management of STI in Uganda. It aims to build and strengthen national capability to generate, access, select, transfer, disseminate and apply scientific knowledge, skills and technological innovations for the realization of Uganda's socio-economic and development objectives, and to ensure sustainable utilization of natural resources (MFPED, 2009). The UNCST and Parliamentary Committee on Science and Technology (2003) are the principal STI governance institutions in Uganda. UNCST is a semi-autonomous agency under the MFPED. The NDP proposes to establish a separate ministry for science and technology. The Parliamentary Committee on Science and Technology oversees matters of STI in Parliament, and advocates for desirable legislations for STI in the country. Complementary institutions which support STI governance exist, notable among which is Uganda National Academy of Sciences (UNAS). The Academy was established and nurtured by UNCST in 2000, and is supposed to provide independent, well researched opinions and recommendations on topical STI issues. It is important that these organizations talk to each other, particularly to lay strategies of how to integrate STI in development planning, mechanisms to translate STI policies into actions, and also chart a way of how to broker relationships among other actors in the innovation system.

Financing: STI is mainly in public research institutes and universities. Financing for STI is predominantly by government and development partners. For example, in 2007/08 financial year, government expenditure on research and development was estimated at 42%, development partners 51%, and other sources 7%. Government pays mainly for administrative costs such as utilities, maintenance and personnel. Contribution from the private sector is miniscule. Total annual national expenditure on R&D as percentage of GDP averaged 0.3% between 2003/04 and 2007/08 (UNCST, 2008). This is very low compared to say South Africa which spends between 0.8% and 1%, and Sweden 4% annually (OECD, 2007). Scientists in Uganda have no option but to rely on grants from abroad. There is increasing need to have stable and more sustainable domestic funding arrangements for STI. Successful countries like South Africa and Sweden have dual schemes for public funding of STI. The first is direct STI funding to research organizations and universities. The second is a national competitive funding mechanism. It is possible for Uganda to adopt this same dual approach because it already has a National STI Fund established under section 20(3) of the UNCST Act (Cap 209). Besides, through the US$ 30 million Millennium Science Initiative Project (2006 -2012), reasonable capacity has been built within the UNCST to operate national competitive grants for STI. The consolidation of this competitive funding scheme would also open up possibilities for bilateral and multilateral cooperation in STI, much to the benefit of Ugandan scientists. This would also be a key marker of the process of integrating STI into national development planning.

CONCLUSIONS

The integration of STI in national development planning processes is possible. This is demonstrated by the inclusion of STI in the NDP as a sector that provides institutional and infrastructural support to the production of goods and services. However, this should not be an end in itself. Integration of STI into national development planning is a process; not a single event. It will be important not only to focus on the likely tangible STI outputs in the NDP, but also on the process by which innovation takes place. This implies that the implementation of the STI provisions in the NDP ought to be undertaken within the context of the national innovation system, with due consideration to the relationships between the actors in the system. Further, the successful designation of STI in the NDP has demonstrated that home grown STI solutions are possible. Exogenous influences on national STI reforms are important, but by themselves may be inadequate to ensure effective integration of STI in the national development planning process.

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3.3. Paper 2

Structure and Dynamics of Uganda's Technological Innovation System

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ABSTRACT

This paper provides insight into Uganda's evolving innovation system. The framework used to gain this insight presents science, technology and innovation as a function of financing, governance, human capital and the strength of interactions within and across the functional spheres. From the framework, it appears universities and public research organizations are playing a major role in building Uganda's innovation system. Public research organizations should, however, collaborate more closely with universities, and be more pragmatic in technology dissemination. It seems that in Uganda the public sector will continue to play a leading role in fostering innovation in the foreseeable future as the private sector grows. A crucial element of the public sector support is to have in place stable merit-based system of science funding where competitive grants are awarded annually for research and innovation.

Keywords: Low Income Countries, Innovation, Innovation System, Research, Science, Technology, Uganda

INTRODUCTION

In 2009 Uganda passed a national science, technology and innovation policy. The policy provides a broad framework for investment and capacity building in science and technology as well as regulation of scientific conduct. It lays out strategies intended to help Uganda meet its aspiration for a science, technology and innovation-led growth and development. To this end, science, technology and innovation was for the first time designated in Uganda's National Development Plan for the period 2010-2015 as a sector that provides institutional and infrastructural support to the production of goods and services (Ministry of Finance Planning and Economic Development (MFPED), 2010; MFPED, 2009). A specific science, technology and innovation plan has been prepared.

These recent policy developments show that Uganda is making some effort to build its innovation system. Many countries around the world are building their innovation systems as a development and competitiveness strategy. The European Union, for example, wants to transform into an "innovation union" (European Commission, 2011). Finland in 2009 re-evaluated its innovation system to prepare it for future growth challenges, and South Africa has a ten-year innovation strategy (2008-2018) as its pathway to a knowledge-based economy. Following these examples, Uganda, indeed like other countries in the region such as Ethiopia, Kenya, Mozambique, Tanzania, and Zambia, to mention a few, has made “innovation” an integral part of its traditional science and technology policy (MFPED, 2009; UNESCO, 2009). Although this is a welcome move, it is not sufficient to foster innovation. Understanding how key organizations and firms in the innovation process interact and learn from each other, and the factors which influence such interactions, will be crucial for effective implementation of the science, technology and innovation policies.

Therefore, the aim of this paper is to provide insight into Uganda's evolving innovation system. The paper is limited to a discussion of the structure and functional elements of Uganda's innovation system. Key actors are identified and their relationship in the pursuit of science, technology and innovation is described. For purposes of this paper, science, technology and innovation are taken together to mean a dynamic process involving discovery and generation of new knowledge and the application of knowledge to develop new and/or improve goods and services. In this sense, science, technology and innovation is the means by which new products and new processes are developed and deployed to use.

The paper is organized as follows: A review of the relevant literature is in Section 2. Section 3 introduces a framework used to discuss the structure and functional elements of Uganda's evolving innovation system. This is followed by results and discussions of the functional elements in Section 4. Section 5 is concluding remarks.

Innovation System, What is It?

Innovation system is a concept first introduced in the 1980s and 1990s by Christopher Freeman, Bengt-Ake Lundvall and Richard Nelson (Lundvall, Joseph, Chaminade, & Vang, 2009; Godin, 2009; Lundvall, 2007; Archibugi, Howells, & Michie, 1999). It refers essentially to interactions among diverse groups of actors involved in the production, diffusion and use of new and economically useful knowledge (Lundvall, 2010; Fischer, 2001). Lundvall recently described an innovation system as an 'open, evolving and complex system that encompasses relationships within and between organisations, institutions and socio-economic structures, which determine the rate and direction of innovation and competence building emanating from processes of science-based and experienced-based learning' (Lundvall, et. al, 2009). For Lundvall learning is crucial in the innovation process. Such learning may be through formal educational and scientific organizations such as universities and research organizations; or it can be learning by doing, using and interacting such as is common in the workplace. Edquist and Johnson (1997) elaborate further that an innovation system has two components: organizations and institutions. Organizations are the actors or players, e.g. universities, research organizations or firms. Institutions are the common habits, rules, laws, and customs that influence the way the organizations relate. The patent law is an example of an 'institution'. It gives inventors the right to exclude others from exploiting their inventions over a prescribed period of time. Another example of an 'institution' could be the requirement to obtain informed consent from human participants in clinical trials. Institutions evolve with new values and organizations transform as a result.

Therefore, innovation systems are dynamic; with people learning as they interact (Lundvall, 2010).

Innovation systems, however, differ across countries and communities. For example, the innovation system of South Africa may differ from that of Uganda. Countries structure and build their innovation systems differently according to their unique customs and traditions, political and socio-economic conditions. But regardless of the differences there might be, innovation systems usually have the same goal, which is, to 'support the development, diffusion and use of innovations' (Chaminade & Edquist, 2006; Edquist, 2001). Here 'innovations' refer to new ideas or practices or new or improved goods and services introduced in a society (Lundvall, 2007; Rogers, 2003; Witt, 2002). These could be products, i.e. new or better goods and services, or processes, i.e. new ways of production which may be technological or changes in management style (Chaminade & Edquist, 2006). Innovations may be radically new, for example, when a new malaria vaccine is introduced; or they could be existing technology that finds a new application elsewhere, for example, when a local bank introduces internet banking services which is already in use somewhere else.

Building blocks of an Innovation System

As of now, there is no single way of describing the structure of an innovation system. Of recent, however, a number of scholars have opted to study innovation systems in terms of their functions or building blocks. These scholars argue that besides identifying organizations (actors) and what they do, knowledge about the system's structure and the way it functions is important to foster innovation (Liu & White, 2001; Edquist, 2001). Consequently, many variants of functions or building blocks of an innovation system have been put forward. Chaminade and Edquist (2006) as well as Hekkert et al. (2007) did an extensive review of functions of innovation systems. Table 3-1 is adapted with modifications from Chaminade and Edquist (2006). It is a summary of some of the functions of innovations systems suggested in literature.

Table 3-1: Activities (functions) in innovation systems

Author(s)	**Definition of function or activity**	**Main criteria for classification**	**Breakdown of functions, activities or building blocks**
Edquist, (2005)	Factors that influence the development and diffusion of innovation	Determinants of the innovation process	1. Knowledge inputs to the innovation process 2. Demand-side factors 3. Provision of constituents in system of innovation 4. Support services for innovating firms

Furman, Porter, & Stern, (2002)	Building blocks required to produce and commercialize a flow of technologies new to the world over the long term	Determinants of national innovative capacity	1. Strong innovation infrastructure 2. Strong innovation environments (incl. input conditions, demand conditions, related and supporting industries and context for firm strategy and rivalry) 3. Linkages between 1 and 2.
Galli & Teubal, (1997)	Factors affecting the production and diffusion of innovations	Activities according to type of organization (hard or soft)	Hard functions 1. R&D 2. Supply of scientific and technical services to third parties Soft functions 3. Diffusion of information, knowledge and technology to bridging organizations. 4. Policy making by government offices 5. Design and implementation of institutions 6. Diffusion/divulgation of scientific cultures 7. Professional coordination through academies, professional associations.
Johnson & Jacobsson (2003)	Factors that affect the knowledge production processes	Knowledge production processes that can be influenced by public policy	1. Creation of new knowledge 1. Guidance of the research process 2. Provision of resources 3. Generation of knowledge economies 4. Dissemination of market information
Xielin Liu and Steven White (2001)	Fundamental activities of innovation systems	Performance implications of a system's structure and dynamics	1.Education 2.R&D 3.Implementation (or manufacturing), 4.End-use (i.e. customers of the product) and 5. Linkage

OECD (2002)	Core blocks in the system of innovation to be considered in a comprehensive innovation policy	Innovation policy	1.Enhancing firm innovative capacities 2. Exploiting power of markets 3.Securing investment in knowledge 4.Promoting commercialization of publicly funded research 5. Promoting cluster development 6. Promoting internationally open networks
(Fischer, 2001)	Building blocks of an innovation system	Elements encompassing the innovation process	1. Manufacturing sector (manufacturing firms & their R&D labs) 2. Scientific sector (education & training; universities & research organizations) 3. Sector of producer services (support to industrial firms) 4. Institutional sector (regulations, financing, rules)
(Hekkert et al., 2007)	Functions of technological innovation systems	Processes which take place in an innovation systems	1. Entrepreneurial activities 2. Knowledge development 3. Knowledge diffusion through networks 4. Guidance of the search (i.e. long term goals set by gov't) 5. Market formation 6. Resources mobilization 7. Creation of legitimacy
(Hekkert et al., 2007); (Bergek, Jacobsson, et al., 2008a); (Bergek, Hekkert, & Jacobsson, 2008)	Functions of technological innovation systems	Processes which take place in an innovation systems	1. Knowledge development and diffusion 2. Influence on the direction of search 3. Entrepreneurial experimentation 4. Market formation 5. Resource mobilization 6. Legitimation 7.Development of positive externalities or "free utilities"

(Lundvall, 2010)	Elements of a national system of innovation	Differences in structure of production systems and institutional set up of nation states	1. Internal organization of firms 2. Inter-firm relationships 3. Role of the public sector 4. Institutional set up of the financial sector 5. R&D-intensity and R&D-organization

Source: Adapted - with modification - from Chaminade and Edquist (2006)

Describing an innovation system in terms of its functions has attracted interest of many scholars. It is a subject of ongoing discussions (See Table 3-1). This paper makes a contribution to the ongoing discourse by introducing another dimension of functions (or in this case, a framework) which could be used in deliberations on innovation systems particularly in low income countries. The framework is used to provide insight into Uganda's evolving innovation system. It uniquely recognizes the distributed and heavily decentralized way knowledge is currently produced and used in Uganda[1].

The Framework

The framework consists of four functional elements. These are: Science, technology and innovation (Sti), Financing (F), Governance (G), and Human Capital (Hc) (see Figure 3-1). Assuming that the primary goal of any innovation system is to "support the development, diffusion and use of innovations" (Chaminade & Edquist, 2006), then:

$$\text{Sti} = f(\text{F, G, Hc}, r),$$

where r denotes the strength and intensity of the interactions (and learning) both within and across the functional elements or spheres. Science, technology and innovation (Sti) in this case represents dynamic processes, such as discoveries, inventions, knowledge generation, product development, dissemination and diffusion of innovations. Governance (G) includes policies and plans, laws and regulations, standards and guidelines which directly or indirectly guide the Sti process. Financing (F) includes funding for Sti activities, e.g. grants for research and innovation, venture capital (e.g. the Youth Entrepreneurship Venture Capital Fund announced in Uganda's 2011/12 national budget speech), direct support from government treasury or private sector and development partners. Human capital (Hc) involves educational and training activities aimed at imparting knowledge and skills necessary for Sti. It also includes knowledge tacitly acquired in the course of work or through experience. Universities, firms and other organizations engaged in local skills development, as well as schools and business, technical and vocational education and training colleges are the primary actors that supply the necessary human capital.

Within each functional sphere (Sti, F, G and Hc) actors operate on a continuum oscillating between sole role (sr) player, e.g. a full time researcher, and dual role (dr) player

1 Compare mode 2 knowledge production, (Nowotny et al., 2001).

e.g. a professor involved in both teaching and conducting research. Across functions an actor may perform multiple roles (mr), e.g. a professor who lectures at a university, does research, but also serves as a board member of a governmental agency. An actor may be an individual or an organization or a firm. Actors performing the same function may interact and learn from each other at specific times and situations within that functional sphere; but they may also interact and learn across functions (Figure 3-1).

RESULTS AND DISCUSSION

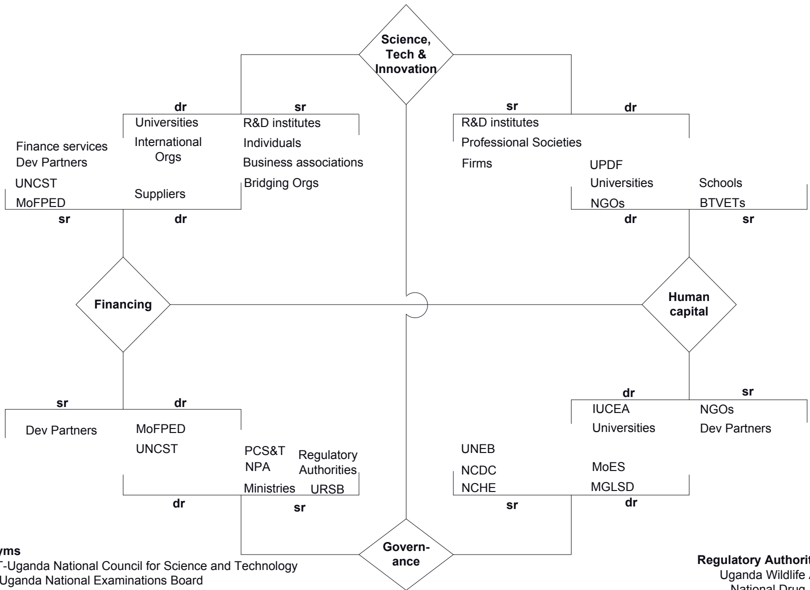
Using the Framework: the Case of Uganda

The information used in the following section to illustrate the various functional elements of Uganda's innovation system was obtained by reviewing key science and technology related policy documents. These documents included the national science, technology and innovation and related policies, institutional reports, workshop proceedings, reports of scientific meetings, comprehensive national development frameworks, laws and regulations, research databases in Uganda, journal articles, papers and related work on innovation systems. These documents were read; key points were noted and summarized. Additional information was gleaned from science and technology policy dialogues, meetings and events both within Uganda and abroad.

Science, Technology and Innovation

Science, technology and innovation in Uganda can be traced back to the pre-industrial iron ore discoveries around Lake Turkana in Kenya, and carbon steel industry around the shores of Lake Victoria (Teng-Zeng, 2006). But later during the colonial era (1894-1962), science, technology and innovation was predominantly in health and agriculture; specifically, research on tropical diseases (malaria and sleeping sickness), cash crops (cotton, coffee, and tea) and fisheries (Teng-Zeng, 2006; East African Community (EAC), 2000). Tsetse control and fisheries research were conducted in eastern Uganda (i.e. National Livestock Resources Research Institute), while tropical diseases research was done in central Uganda (i.e. Uganda Virus Research Institute at Entebbe). Interest in studying the African way of life led to the establishment of an East African Institute of Social Research at Makerere in 1948 (now Makerere Institute of Social Research). To date humanities, health, agriculture and natural sciences continue to dominate the fields of research in Uganda. In 2008, for example, social sciences and humanities accounted for 36 per cent of the research conducted in Uganda followed by health (31 per cent), natural sciences (21 per cent), and agriculture (ten per cent) and engineering and technology two per cent (Ecuru et al., 2008). Uganda needs to do more to promote research and innovation in the engineering and physical sciences fields as well as the foundation for value addition and manufacturing. Also latent potential of the informal sector engaged in metal fabrication, wood works, food and farm produce and herbal medicines is largely untapped.

Public universities and research organizations account for the bulk of scientific and technological activities in the country. Unlike in South Africa, where private companies account for almost half of the research and innovation investment, the contribution from private companies in Uganda is still very small. If Uganda should achieve its goal of becoming a middle income country as soon as possible, public universities and research organizations have to be more proactive in translating their research products into commercial ventures and enterprises.



Acronyms
UNCST-Uganda National Council for Science and Technology
UNEB-Uganda National Examinations Board
NCDC-National Curriculum Development Centre
NCHE-National Council for Higher Education
URSB-Uganda Registration Services Bureau
NPA-National Planning Authority
MoFPED-Ministry of Finance, Planning & Economic Development
MoES-Ministry of Education & Sports
MGLSD-Ministry of Gender, Labor & Social Development
IUCEA-Inter-University Council for East Africa
PCS&T-Parliamentary Committee on Science & Technology
BTVETS-Business, Technical, Vocational Education & Training Sch.
UPDF- Uganda Peoples' Defense Forces
NGOs-Non-Governmental Organizations

Regulatory Authorities, e.g.
Uganda Wildlife Authority
National Drug Authority
National Forestry Authority
Uganda National Bureau of Standards
Public Procurement and Disposal Authority
National Environment Management Authority

Public R&D Institutes, e.g.
National Agricultural Research Org (with its 17 institutes
Uganda National Health Research Org (with its 4 institutes)
Uganda Industrial Research Institute
Joint Clinical Research Centre

International Organizations, e.g.
International Potato Centre
Centres for Disease Control, USA
International AIDS Vaccine Initiative
Medical Research Council, UK
Makerere Univ-Johns Hopkins University Collaborations
Epicentre, Mbarara
Uganda-Case Western Research University
National Institutes of Health, USA
Makerere Univ-Univ of New Jersey Research Collaboration
Malaria Consortium

Bridging Organizations, e.g.
National Agricultural Advisory Services
Coffee Development Authority
Uganda Export Promotions Board
Cotton Development Organization
Program for Biosafety Systems
Science Foundation for Livelihoods and Development
Advocates Coalition for Development and Environment

Private R&D Institutes, e.g.
Med Biotech Laboratories LtD
Centre for Basic Research
Rakai Health Research Institute

Business Associations, e.g.
Private Sector Foundation
Uganda Manufacturers Association
Uganda National Farmers Federation

Development Partners, e.g.
World Bank
Swedish International Development Agency
United States Agency for International Development
European Union
Royal Dutch Embassy
Belgium Development Cooperation
German Development Cooperation
Government of Norway

NGOs, e.g.
Gatsby Trust-Uganda
Appropriate Technology-Uganda
SNV-Netherlands Dev. Org-Uganda
Prolinnova-Uganda
Swisscontact International
African Innovations Institute-Uganda
World Vision-Uganda

Universities, e.g.
Makerere University
Mbarara University of Science & Technology
Busitema University
Gulu University
Kyambogo University
Uganda Christian University
Uganda Martyrs University
Islamic University in Uganda
Bugema University
Ndejje University
Nkumba University
Kampala International University

Professional Societies, e.g.
Uganda National Academy of Sciences
Institute of Professional Engineers
Uganda Society for Health Scientists

Ministries, e.g.
Ministry of Trade & Industry
Ministry of Water & Environment
Ministry of Agriculture, Animal Industry & Fisheries
Ministry of Energy & Mineral Development
Ministry of Works and Transport
Office of the President
Ministry of Defense
Ministry of ICT

Figure 3-1: Actors and functions in Uganda's innovation system

Human capital

Human capital constitutes the pool of knowledgeable and skilled people capable of generating new ideas, and transforming ideas into socially valuable and economically viable goods and services. In Uganda this pool is still small. Human capital potential is shaped by the educational system of a country and by the learning environment in firms and other organizations.

Uganda's education system comprises two to three years of pre-primary schooling, seven years of primary, four years of lower secondary, two years of upper secondary, and three to five years of undergraduate study. Technical and vocational colleges offer one to three year diploma and certificate courses providing technical skills in a variety of scientific and technological fields. Sustained efforts are needed to attract students into science and engineering career programmes, especially at universities. At the moment less than 25% of students enrolled in universities are for science and engineering programmes, which is about half the international average (Barugahara & Lutalo, 2011).

For a long time, Uganda had only one university, i.e. Makerere University, which started as a technical college in 1922 and was accorded a university status in 1949. Higher education reforms which took place in the early 1990s paved way for emergence of private universities. By the end of 2011 there were five recognized public universities and over 22 private ones. The Universities and Tertiary Education Act of 2005 further gave autonomy to universities and created the National Council for Higher Education to ensure good standards (high quality) in higher education.

Most of the reforms taking place in Uganda's education sector are geared towards supply of the much needed scientific workforce. Since 1996, every child of school going age (i.e. six to 12 years) must attend primary school free of charge under the universal primary education program. Starting 2006 government further adopted a phased introduction of universal secondary education. The study of science subjects is compulsory in lower secondary education; and since 2005, 75 per cent of all government sponsorship (currently 4,000 students annually) for undergraduate student enrolment in public universities is towards science based courses. As a government policy, all public universities established after Makerere University are supposed to emphasize science disciplines. However, they often end up with more humanities and arts students. By recruiting more students into humanities and arts courses, public universities can generate income internally to meet shortfalls in government funding. Unless government intervenes with more sustained funding to the higher education sector, public universities may fail to achieve the policy goal of producing more science and engineering graduates. A continuing challenge cutting across the entire education sector in Uganda is ensuring higher quality of learning at all levels and reforming curricula to meet the changing skills demand in the economy.

Capacity for postgraduate training at Ugandan universities, other than Makerere University is still very low. Owing to the limited facilities, a significant number of Ugandan students seek graduate studies abroad. Over the years, Makerere University has built considerable capacity to offer science-based postgraduate (PhD and MSc) training. Makerere University could, therefore, take advantage of its unique position and capabilities to expand its graduate school. This opportunity is somewhat identified in the University's strategic plan for the period 2008/09-2018/19 which aims to transform the university into a research-led university, essentially producing Masters and PhDs for other universities. To achieve this goal, however, would require the university to substantially reduce enrolment for undergraduate students. It would also mean losing revenue from undergraduate private students. Therefore, realizing the goal of a research-led university may take some time.

Governance

From independence in 1962 until the early 1990s policy for science, technology and innovation was such that research and technology dissemination were carried out within government's line ministries and departments. In 1970 a National Research Council was created by a Cabinet decision to guide and coordinate research in Uganda. This body became the Uganda National Council for Science and Technology (UNCST) duly established by Act of Parliament (Chapter 209) in 1990. Public Sector Reforms in the 1990s detached research from government ministries and line departments and created autonomous research organizations such as the National Agricultural Research Organization (established in 1992 but restructured in 2005 by the National Agricultural Research System Act of 2005). Granting autonomy to research organizations was aimed at reducing red tape, improving accountability and overall efficiency. However, it tended to alienate government from research and academia and vice versa. Interactions between research organizations and universities and government and industry became more difficult to achieve in practice.

Earlier on in 1990 need was felt for an explicit national policy on all fields of science and technology, hoping that it would provide a coordinated framework for science and technology development in the country. The first attempt to formulate this policy was at a National Workshop held toward the end of 1991. A draft of the national science and technology policy was prepared in 1993. The draft policy underwent several revisions until it was finally passed by government in August 2009. The goal of the policy is to strengthen Uganda's capability to generate, transfer and apply technologies, ensuring sustainable utilization of natural resources for development. Besides this framework policy, sectoral science and technology policies also exist including, for example, the National Agricultural Research Policy 2005 and the National Biotechnology and Biosafety Policy 2008.

Uganda has no stand-alone ministry for science and technology unlike its neighbours Kenya and Tanzania or South Africa for that matter. The Ministry responsible for science and technology is that of Finance, Planning and Economic Development, which is also the parent ministry to which UNCST belongs. Coordination of science and technology matters is, therefore, the responsibility of the UNCST. The UNCST was established in 1990 to advise on and coordinate the formulation of an explicit national policy on all fields of science and technology; and also to coordinate research and development, and facilitate science and technology integration into all sectors of the economy, among other functions. Over the years, UNCST has grown tremendously and evolved into an organization with three major clusters of roles. First, it functions as a national research and innovation funding agency. In some countries separate organizations are created and dedicated to play this role. In South Africa, for example, such a role is played by the National Research Foundation and other Research Councils. Second, UNCST plays the role of a science and technology policy think tank and advisory body to government. Such a function entails guiding the direction, setting goals and determining priorities for strategic investments in science, technology and innovation. Juma (2011) argues that such a function should be positioned at the highest possible level in government such as at presidential or cabinet level. Third, UNCST acts as a regulatory body in some situations e.g. for biosafety, human subjects research and access to genetic resources. Because these are crosscutting themes and sometimes involve new and emerging technologies, it is difficult to place them in any one single organization, other than the UNCST.

The challenge, however, is that the three major clusters of roles currently played by the UNCST are huge mandates in themselves, and may with time overwhelm the capacity of UNCST as an organization. This is probably why a dedicated ministry for science and technology has been proposed (MFPED, 2010). The other challenge is that as the trends of research and innovation keep rising and knowledge production becomes increasingly diversified and distributed, the three clusters of roles could potentially conflict under one roof. If these clusters of roles are to be played more effectively in future, then having them executed in separate houses might be a prudent strategy as long as the resource envelope is able to sustain them as such.

As for legislation, there are different pieces of it which regulate various aspects of scientific conduct. For example, the National Environment Management Authority Act 1995 provides for environmental impact assessment of major scientific projects. The National Drug Authority Act of 1993 regulates clinical trials. The Uganda Wildlife Authority Act of 1996 regulates research in wildlife protected areas. There are other laws, regulations and guidelines, e.g. for quality of commercial and consumer products, intellectual property protection, plant quarantine, human research protection, biosafety, and radiation safety.

Therefore, it appears Uganda is not short of the basic policies, laws and regulations to guide science, technology and innovation. The key issue is the extent to which these policies and laws are harmonized to support research and innovation in the country. Although new policies and laws may be justifiable in some situations, more effort should be devoted to implementing, reviewing and consolidating the existing ones. Responsible agencies should have the means to quickly adjust their policy and legal regimes to accommodate significantly new and emerging areas of science, technology and innovation.

Financing

Financing for science, technology and innovation in Uganda is predominantly by government and development partners. In 2007/08 financial year, government's share of expenditure on research and development was about 42 per cent, development partners 51 per cent and other sources seven per cent. Government support was mainly for administrative costs such as utilities, maintenance and personnel. Contribution from private sector was miniscule. In middle income countries, private sector usually spends more on research and development. For example, in 2004/05 the business sector in South Africa financed 45% of research and development and performed 58% of total research and development, while international sources amounted to only 15% (OECD, 2007). Scientists in Uganda rely on grants from abroad, which are very competitive to win, and which sometimes may not be properly aligned to the country's development needs. For many Ugandan scientists, having good grants proposal writing skills is paramount and forging links with other scientists abroad is absolutely essential. In addition, having a supportive local research environment, e.g. efficient administrative processes, less cumbersome regulatory systems for research and less burdensome tax regimes for scientific equipment, would be necessary to attract more foreign research investment.

Between 2003/04 and 2007/08, total annual national expenditure on R&D as percentage of GDP averaged 0.3 per cent (Ecuru et al., 2008). This is very low compared to South Africa, which spent between 0.8 per cent and one per cent of its GDP on research and development during the same period (OECD, 2007). Uganda should work towards spending at least one per cent of its GDP per annum on research and development in the medium term as recommended by the African Union Summit of 2007 in Addis Ababa, Ethiopia.

A key missing link in the financing of science, technology and innovation in Uganda is the absence of a stable merit-based competitive funding scheme coupled with weak contribution from the private sector. The Uganda Millennium Science Initiative (MSI) launched in February 2007 by President Y.K Museveni was the closest to having a national competitive/merit-based system for science funding. The MSI was a project worth US$ 33.35 million over 5 years co-financed by the government of Uganda (US$ 3.35 million) and the World Bank (US$ 30 million), and implemented by the UNCST. By the end of 2009 UNCST had awarded competitively a total of 39 grants each ranging between US$ 0.25 million to US$ 1.25 million for three to four years. Impressive results have so far been reported, including strengthening tertiary science and engineering curricula, potentially commercializable research products, outreach events, more skilled science and engineering graduates, etc. Building on the MSI model of financing research and innovation could be one way the Uganda government would operationalize the National Science and Technology Fund established in 1990 under Section 20 (3) of the UNCST Act 1990 (Chapter 209). The MSI project in Uganda appears to have been a step towards building a merit-based system for science funding in the country.

A merit-based system for research and innovation funding is desirable for harnessing ideas and knowledge, and nurturing local talent. It would also encourage creativity and a culture of innovation in Ugandan universities, research organizations and firms. However, developing and sustaining such a system might also depend on the extent to which it is consistent with and supported by the current national budgeting regime.

Uganda's annual national budget is arrived at through a consultative process involving Sector Working Groups (SWGs). A SWG is a forum for negotiation, policy dialogue and agreement on priority plans as well as budget allocations within the sector. Presently designated SWGs are: Agriculture; Lands, Housing and Urban Development; Energy and Mineral Development; Works and Transport; Information and Communication Technology; Tourism, Trade and Industry; Education; Health; Water and Environment; Social Development; Security; Justice, Law and Order; Public Sector Management; Accountability; Legislature; and Public Administration (MFPED, 2011). Ideally, any government ministry or agency should fit in one of these SWGs. Universities, for example, belong to the Education SWG, the National Agricultural Research Organization is in the Agriculture SWG, and UNCST belongs to the Accountability SWG, where its parent Ministry of Finance, Planning and Economic Development falls. In principle, therefore, each agency with significant science, technology and innovation activities should vie for financial resources within their respective SWGs. Since science, technology and innovation cuts across all the SWGs, it seems logical and plausible to have it rationalized within each SWG. However, this approach may not be welcomed by some members of the scientific community who strongly believe that science, technology and innovation deserves a sector status and, therefore, should also be designated a SWG. The SWGs, notwithstanding, it is important that agencies with significant science, technology and innovation activities have opportunities for joint cooperation in research and innovation with universities, research organizations and firms. This would be possible if government encouraged dual funding systems for research and innovation which, on the one hand, involves direct funding to universities and research organizations, and on the other, having in place a stable merit-based system where grants are competitively awarded annually to individuals and research groups. Countries with remarkable progress in research and innovation use multiple streams of merit-based as well as direct funding support to research organizations and universities. South Africa, for example, runs a merit-based system for funding scientific projects through the National Research Foundation, Technology Innovation Agency, Medical Research Council, among others. Uganda needs to do the same to bolster its innovation system.

CONCLUSION

In trying to understand the structure and dynamics of Uganda's innovation system, universities appear to be playing a more active role (Figure 3-1). They are active in human capital development, and are the centre for most scientific and technological activities in the country. Universities in Uganda participate quite significantly in policy making processes (governance). University staff are often hired as consultants or are appointed to serve as members of advisory boards and technical committees of government agencies and some private sector firms. Some public universities have started engaging in business enterprise development. Makerere University, for example, has an upcoming business incubator for innovations in foods and beverages, and is also active in creating and supporting business clusters. In Uganda, where the private sector is still weak, universities can play an important role in creating new enterprises or enhancing the competitiveness of the existing ones. Ugandan universities can harness their intellectual property assets in a pragmatic way to encourage private sector growth. Public research and development organizations can also do the same, particularly if they overcome rigid institutional boundaries which appear to confine them to research only.

Using the four functional spheres Sti, G, Hc, and F, therefore, may be an alternative way of understanding the structure and dynamics of an innovation system, particularly in a low income country like Uganda. The framework, with its inherent limitations, recognizes the diversity of actors and their contribution to building Uganda's innovation system. However, to foster innovation, it is absolutely essential to create conditions for the actors to cooperate, collaborate and interact more intensely across each of the functional spheres. Further work is needed to assess the framework in other settings and to understand how it can be used to create enabling conditions for interaction both within firms and organizations and among different actors in the innovation process.

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3.4. Paper 3

Innovation Characteristics of Formal Manufacturing Firms in Uganda

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ABSTRACT

Many low income countries are seeking accelerated economic growth and transformation into middle income countries by promoting private sector development. However, private sector in these countries faces a number of challenges, one of which is to become more innovative and competitive both locally and internationally. This paper is based on an explorative study conducted in 2011/12 of 71 formal manufacturing firms randomly selected from subsectors of food and beverages, chemicals and pharmaceuticals in Uganda. The purpose of the study was to understand the characteristics of firm innovation including the modes of interaction and learning in the process. Results reveal that more than 60 per cent of the firms had significantly improved their products, or introduced a new product, changed their management systems and manufacturing processes in the last three years. These innovative activities were mainly incremental and adaptive in nature and were carried out mostly within the firm (40 per cent) but with some assistance from other firms abroad (20 per cent). Local universities and research organizations appear not to have participated much in the firm's innovation processes. The fear for competition and lack of trust appeared to have prevented many firms from interacting with other firms and organizations. Firms, however, prefer conferences, business associations, inter-firm visits, and joint programs as means to foster interactions between them and other organizations. These findings contribute to on-going discourse on strengthening innovation capabilities of firms and the role of local universities and research organizations in supporting firm growth and competitiveness in low income countries.

Key words: Firm, Innovation, Low Income Countries, Manufacturing, Triple Helix, Role of University, Uganda

INTRODUCTION

Manufacturing is one of the ways of promoting value addition and agro-processing. The latter are vital for increasing household incomes of the majority of Ugandans engaged in agricultural production and natural resource management. However, growth in manufacturing generally has not only been slow, but has also been declining over the past few years (Ministry of Finance Planning and Economic Development (MFPED), 2012). Recently the World Bank reported a slump in manufacturing from 13.8 per cent in the 1990s to 6.6 per cent in the 2000s, and observed that contribution of manufacturing to Uganda's GDP remained stagnant at 7.4 per cent through two decades (World Bank, 2012). This slow growth in manufacturing was partly attributed to electricity shortage and fluctuation of the foreign exchange rate. At the same time, Ugandan manufacturing firms are increasingly challenged to be more innovative and competitive (MFPED, 2010) as other economies in the region and elsewhere around the world bolster their private sector and as markets become more and more liberalised. Efforts are being made to enhance competitiveness of Uganda's private sector, but they are focusing mainly on regulatory reforms to ease doing business and provision of infrastructure and incentives to attract foreign direct investments. The efforts, inter alia, include creation of dedicated organizations like the Private Sector Foundation, Uganda Investment Authority, Uganda Export Promotions Board, and initiatives such as the Competitiveness and Investment Climate Strategy of the Ministry of Finance, Planning and Economic Development and the annual Presidential Investors Round Table, which have a common goal of improving Uganda's business environment and competitiveness in the region and internationally. These efforts notwithstanding, Uganda continues to rank poorly in the global competitiveness index and real growth in the manufacturing sector remains low (World Bank, 2012; Bbaale, 2011). Achieving the desired level of competitiveness requires sustained and consistent support to the aforementioned initiatives and efforts, but equally important is the challenge of building innovation competences of Ugandan manufacturing firms.

Innovations are new ideas or practices or new or improved goods and services introduced in society (Lundvall, 2007; Witt, 2002; Rogers, 2003). Depending on their attributes, innovations can be broadly categorised as product, process and organizational innovations (Edquist, 2001), and furthermore, on whether it is radical (new to the world) or incremental in nature (Freeman, 1995; Oyeleran-Oyeyinka, Laditan, & Esubiyi, 1996). Innovation is critical to a firm's growth and competitiveness (World Economic Forum, 2010); and is an outcome of interactive learning among and between a diversity of actors (Lundvall, 2010; Adebowale & Oyeleran-Oyeyinka, 2012). This paper highlights the characteristics of innovation in formal manufacturing in Uganda (one quarter of the manufacturing sector in Uganda is informal (MFPED, 2012)). The paper is based on an exploratory study conducted in 2011/12 among formal manufacturing firms in the food and beverages, chemicals and pharmaceuticals sub-sectors. These sub-sectors represent the primary production sectors, which closely address Uganda's quest for value addition, agro-processing and agribusiness.

The purpose of the study was to understand the characteristics of firm innovation including firms' nature of interaction and learning. While there is a growing body of literature on firm innovations elsewhere, insufficient empirical data exists on innovations in manufacturing firms of Uganda. It was considered innovation if the firm made significant improvements on its products, or introduced a new product or made changes in its management or organizational system; and whether firms made improvements in their methods of manufacturing, delivering inputs, packaging and distributing goods. Firm interactions and learning were assessed by considering the people or organizations that worked with the firm in the innovation process, where firms acquired their technologies, and scientific and technical information, and the firm's participation in networking events. Other characteristics such as firm size, age, ownership, training, spending on research, and student internships were also considered in the study.

METHODS

Study population and sample size

The study was conducted in 2011/2012 among Ugandan formal manufacturing firms, drawn from three subsectors: foods and beverages, chemicals, and pharmaceuticals. The firms were selected from the 2010/2011 Uganda Manufacturers' Association (UMA) membership directorate which was taken as the sampling frame for the study. UMA is the umbrella organization for manufacturers in Uganda, with membership of over 80% of formal manufacturing firms in the country.

A list of 289 eligible firms was generated from the UMA directorate comprising firms in the foods and beverages (134), chemicals (46), and pharmaceuticals (9) sub-sectors. A sample size of 165 firms was calculated using Krejcie and Morgan (1970) formula for determination of sample size:

$$s = \frac{\chi^2 NP\,(1-P)}{d^2(N-1) + \chi^2 P(1-P)}$$

where s = desired sample size, χ^2 = 3.84 which is the table value of the Chi-square at *d.f.* = 1 for a 5% confidence level, N = population size, P = population proportion (assumed to be 0.5) and d = degree of accuracy (0.05).

Data collection

Questionnaires were investigator-administered to the extent possible. Majority of the respondents, however, preferred completing the questionnaires by themselves (self-administration). All respondents were senior officers of the firms holding a managerial or supervisory position, such as production manager or managing director. Of the 165 firms randomly selected, only 109 were traceable and could be visited. Of the 109 firms 71 responded to the questionnaires. Firms, which could not be reached and those that refused or did not respond to the questionnaire, were all treated as non-respondents, thus giving a 43% response rate. The questionnaire covered firm characteristics, innovations processes, research and development (R&D) expenditure and sources, human resource training, collaboration and networking, constraints to firm interactions, and recommendations for enhancing collaboration and cooperation.

Data analysis

Data were entered in Epidata software and analysed using the SPSS software (SPSS Statistics 17.0). The next section presents the results.

RESULTS

Firms' characteristics

The formal manufacturing firms who completed the questionnaire were by subsector: food and beverages (58 %), chemicals (35 %) and pharmaceuticals (7%). These firms were relatively young, with nearly two thirds (62 %) of them being less than 25 years old (Figure 3-2). Most firms were established either by individuals (39 %), by a group of people (38%) or by a group of companies (18 %). Government established firms were few (4 %), and no firm was established by a local research organization or university. Figure 3-3 shows the firm sizes according to number of employees (OECD, 2005 Oslo Manual, para. 249). No significant association was observed between firm size and firm innovations in the last three years (Table 3-2).

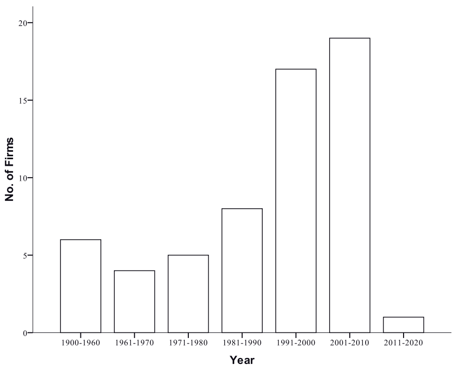

Figure 3-2: Year firm was established

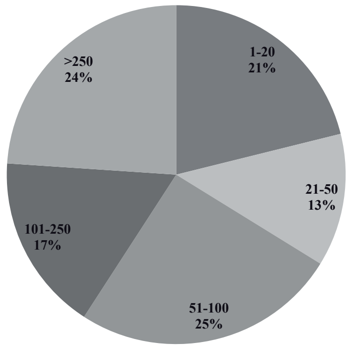

*Figure 3-3: Firm size (by number of employees*Ta

Table 3-2: Relationship between firm innovation and firm size, expenditure on training and research

Firm Innovation	Firm size		Expenditure on staff training		Expenditure on research	
	$\chi^2(4, N=71)$	*p* value	$\chi^2(2, N=71)$	*p* value	$\chi^2(3, N=71)$	*p* value
Improvement on products	2.596	0.627	2.068	0.356	2.167	0.538
New products introduced	1.948	0.745	1.867	0.393	1.306	0.728
Introduced changes in management system	3.825	0.430	2.428	0.196	3.146	0.370

Firm innovations

Innovations by the firms was determined by the firm's significant improvements to products or introduction of new products (product innovation), or changes in management system (organizational innovation) and changes in methods of manufacturing, delivering inputs, packaging and distributing products (process innovation). More than 60% of the firms on average had innovated in the last three years (Figure 3-4). Improvements on products were mainly on quality (39%) and packaging (22%), although to a small extent improvements were also made to increase quantity (7%) as well as branding (6%) of the products. This is illustrated further in Figure 3-5 where nearly three quarters (73 %) of the firms had obtained quality marks and registered trademarks. But no more than one quarter of the firms were involved in filing for patents or negotiating technology licenses.

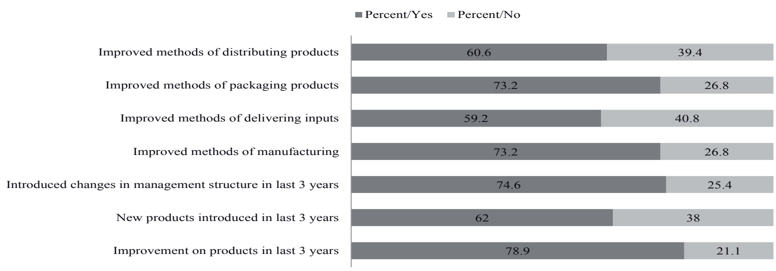

Figure 3-4: Firm's innovations in last three years

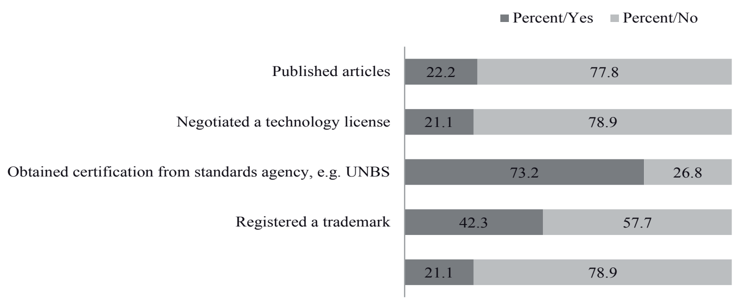

Figure 3-5: Selected indicators of firm's innovative activities

Firm interactions

A wide range of people and organizations were involved in the firm's innovative activities. The involvement of people and organizations were considered to be an important indication of the firm's interaction with other actors, as was also the firm's source of technology acquisition, sources of scientific and technical information, and the firm's participation in networking events. Overall, firms innovated using internal expertise and assistance from other firms abroad (Figure 3-6). Local universities and research organizations did not participate much in the firm's innovative activities during the period covered by the study. Firms, however, worked with government agencies, but these were primarily regulatory agencies notably the Uganda National Bureau of Standards, National Environment Management Authority, Dairy Development Authority, and National Drug Authority.

With respect to technology acquisition, firms used their in-house technical capacity and also acquired technology from abroad (Figure 3-7). Few firms (13 %) acquired technology from a local research organization, and very little technology was obtained from the local universities (3.1%).

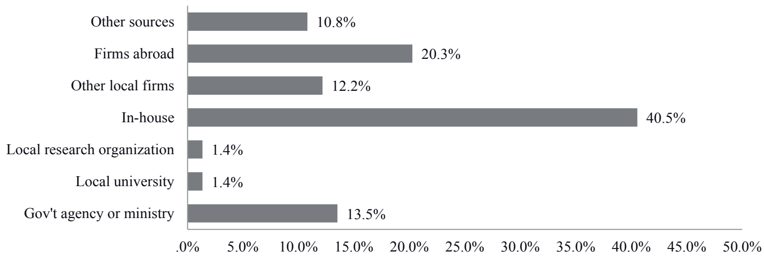

Figure 3-6: People/organizations the firm worked with to improve products

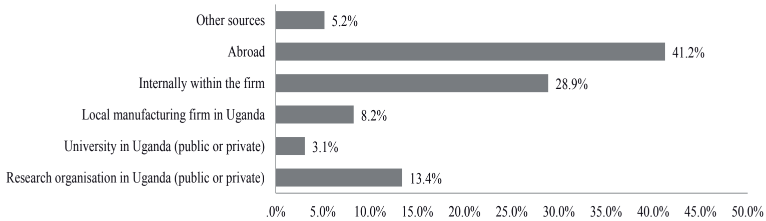

Figure 3-7: Sources of firm's technology acquisition

Firms obtained scientific and technical information from a variety of sources (Figure 3-8). Internet sources, conferences and hiring consultants were the main sources of information. Local universities and research organizations were seldom visited by the firms (less than 4%) for purposes of getting scientific and technical knowledge.

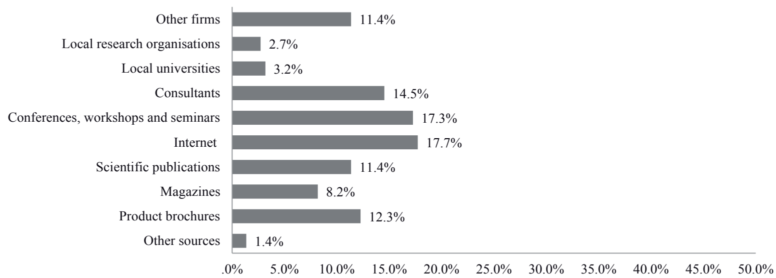

Figure 3-8: Firm's sources of scientific and technical information

There was, however, reasonable indication that firms participated in networking events as shown by their membership to business associations and to boards of public organizations (Figure 3-9). Few firms were part of the university or local research organization board. Association between firm innovation and various aspects of the firm's interactions was not significant (Table 3-4) except for firms who were board members of a public organization.

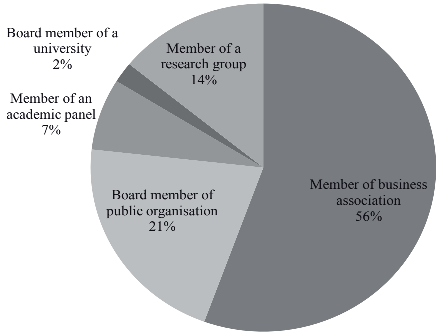

Figure 3-9: Firm's participation in networking events

Firm's research, training and innovation expenditure

Training by far was one of the most important activities of the firms in the period covered by the study. Firms also acknowledged the importance of student interns (more than 90% of firms had student interns the previous year). Training was mostly organized in-house (Figure 3-10). Overall nearly 90% of firms engaged in training activities, with some firms (29.6%) spending between Uganda Shillings 50 and 100 million in last three years (Figure 3-11) on training. Training was also tenable at local universities and business and technical institutes (presumably where firm employees qualified from). The latter are traditional formal training organizations which channel out the scientific and technical workforce. Local NGOs, manufacturing firms both within and abroad also participated in training firm employees as well as government agencies or ministries.

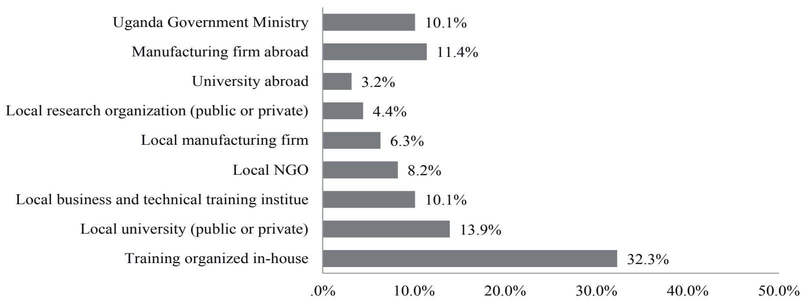

Figure 3-10: People/organization that trained firm's employees in last three years

Slightly more than half of the firms (59 %) undertook research and development in the period covered by the study. Out of these, 64 % spent less than Uganda Shillings 50 million on research in the previous three years (Figure 3-11). Research was financed largely from the firm's own resources (Table 3-3).

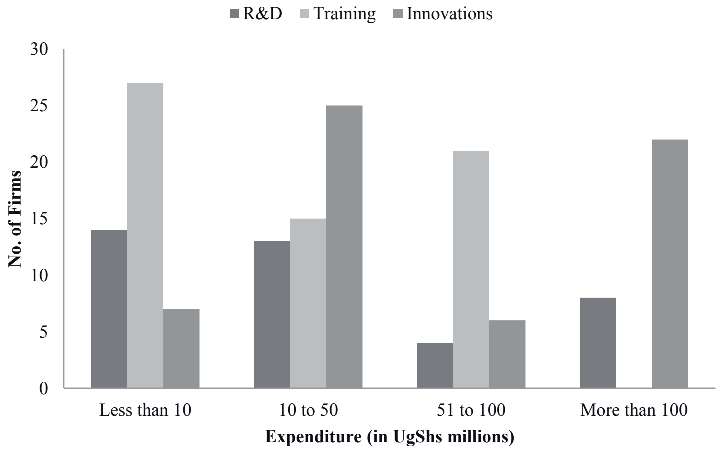

Figure 3-11: Firm's expenditure on research, training and innovation

Table 3-3: Firms' sources of R&D funds

		Responses		
		N	Percent	Percent of Cases
Firms' sources of R&D funds[a]	Self generated funds	44	84.6%	91.7%
	Funds from a local university (public or private)	1	1.9%	2.1%
	Funds from a local research organization (local or private)	1	1.9%	2.1%
	Funds from a donor organization	3	5.8%	6.3%
	Other sources	3	5.8%	6.3%
Total		52	100.0%	108.3%

a. Dichotomy group tabulated at value 1. Note 48 firms reported source of funds, 23 did not report

Constraints to Firm Interactions

Interaction, and especially where learning is involved, is a key factor in ensuring attainment of innovativeness. Knowledge sharing is characteristic of a firm's interactive learning behaviour. More than 70% of firms stated they would freely share their knowledge with other firms or organizations involved in similar or related activities. However, competition and lack of trust (Figure 3-12) were important constraints to firm interactions with other firms and organizations, although some firms (27 %) did not see any constraints. This notwithstanding, firms proposed a variety of ways to improve interaction. The main ones included seminars and conferences, business associations, inter-firm visits, and joint programs (Figure 3-13).

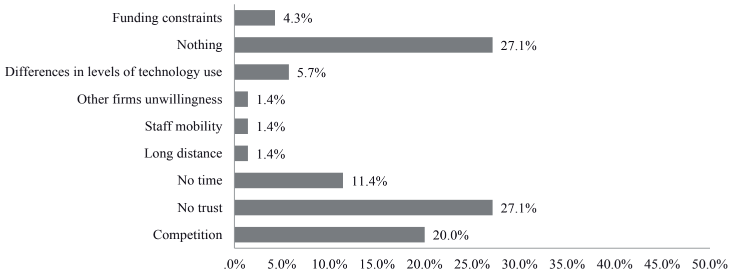

Figure 3-12: Firm's constraints to interaction with other firms or organizations

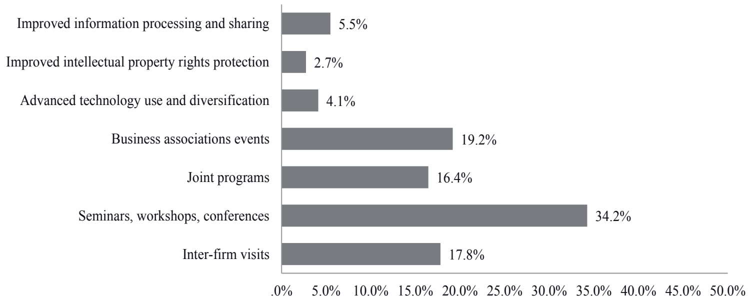

Figure 3-13: Firm's recommendations to promote interaction

Table 3-4: Relationship between various aspects of firm innovations and interactions

Firm interactions	**Firm innovations**					
	Improvement on products		New products introduced		Introduced changes in management system	
	χ^2(1, N=71)	*p* value	χ^2(1,N=71)	*p* value	χ^2(1, N=71)	*p* value
People/Organizations firm worked with						
Gov't agency or ministry	3.118	0.077	1.605	0.205	0.176	0.675
Local university	0.272	0.602	0.622	0.430	0.344	0.557
Local Res' Organization	0.272	0.602	0.622	0.430	0.344	0.557
In-house	1.894	0.169	0.486	0.486	0.786	0.375
Other local firms	0.007	0.931	1.344	0.246	1.104	0.293
Firms abroad	0.014	0.904	0.178	0.673	1.452	0.228
Other source	0.403	0.526	0.001	0.974	0.787	0.375
Firm's source of technology acquisition						
Local Res' Organization	0.036	0.849	1.509	0.219	0.835	0.361
Local university	0.839	0.360	0.029	0.864	0.105	0.745
Local manufacturing firm	0.403	0.526	0.649	0.420	0.787	0.375
In-house	1.298	0.254	0.105	0.746	0.376	0.540
Abroad	0.104	0.747	0.356	0.550	2.985	0.084
Other source	0.004	0.949	0.742	0.389	1.827	0.177
Firm's sources of scientific and technical information						
Other local firms	0.191	0.662	0.584	0.445	0.584	0.445
Local res' organisations	0.078	0.780	2.281	0.131	2.104	0.147
Local universities	2.080	0.149	0.077	0.782	0.043	0.837
Consultants	2.602	0.107	0.167	0.683	0.237	0.627
Conferences	0.000	0.987	0.072	0.788	2.075	0.150
Internet	0.020	0.889	1.136	0.287	2.913	0.088
Scientific publications	0.029	0.864	1.628	0.202	0.037	0.847
Magazines	1.452	0.143	3.143	0.076	2.335	0.127
Product brochures	1.042	0.307	0.761	0.383	1.075	0.300
Other sources	0.839	0.360	0.029	0.864	0.105	0.745

Firm's participation in networking events						
Member of business association	0.311	0.577	0.528	0.467	0.326	0.568
Board member of a public organization	7.988	0.005	0.279	0.597	3.948	0.047
Member academic panel	0.258	0.611	0.077	0.782	2.637	0.104
Board member of a university	1.030	0.310	1.263	0.261	0.699	0.403
Member research group	0.490	0.484	0.173	0.678	0.096	0.757

DISCUSSION

Formal manufacturing firms, especially those in the subsectors of food and beverages, chemicals and pharmaceuticals are actively innovating. The innovations are incremental in nature and relate to product quality, manufacturing process and packaging improvements; and mostly done in-house with moderate support from abroad. This possibly explains why there was no significant association between firm innovation and the various aspects of firm interactions, especially with the local universities and research organizations. It is believed universities and research organizations hold the repository of knowledge and expertise, but they appear not to be actively involved in formal firm innovative processes in Uganda. Anecdotal evidence and case studies have also previously revealed weak links between the academia and industry in Uganda (Kibwika et al., 2009). A similar phenomenon was reported by Oyeleran-Oyeyinka et al., (1996) from their study of industrial innovation by Nigerian firms, except where they observed linkages which were largely informal mainly between research and development institutes and small and medium scale enterprises who presumably had no financial and capital facilities to engage in in-house R&D (Oyeleran-Oyeyinka et al., 1996). It may be argued that research methods, industrial attachments (internships) and project work which are now part of the university science and engineering degree curricula are conferring upon local university graduates appropriate skills for them to engage in innovative activities in firms which eventually employ them. However, to improve the innovative performance of manufacturing firms, local research organizations need to proactively engage with private firms in the innovation process. While conditions for collaboration appear to exist within local manufacturing firms, unlocking them requires firms to gain confidence in the local universities and research organizations as partners in the innovation process. The flip side is that with the economy liberalised and with a significant presence of foreign direct investment, local universities and research organizations become both competitors and complementary actors to their knowledge counterparts abroad. Therefore, having in place the right conditions for cooperation with local firms such as effective systems for intellectual property management and technology transfer as well as incentives for joint projects may enhance local universities and research organizations' attractiveness and participation in firm innovation processes. Initiatives such as the Innovation Systems and Clusters

Programme at Makerere University (Mwamila & Temu, 2006), and the Millennium Science Initiative's private sector cooperation programme (Brar et al., 2011), could play an important catalytic role in bridging the gap between local universities and research organizations, firms and government in Uganda. Strong university, industry and government relations can enhance innovation competence among firms and other organizations (Etzkowitz & Carvalho de Mello, 2004).

Cooperation between firms and different agents in the innovation process is also determined by well-functioning institutions (Oyelaran-Oyeyinka, 2006; Edquist, 2005). From the results it was evident that trademark and standards/certification systems indirectly but importantly contributed to firm innovative activities. Arguably, as firms begin to take competitiveness more seriously, efficient and effective intellectual property management and quality certification systems become vital support mechanisms to the innovation process. Trademarks uniquely identify a firm's products, and may give the firm an edge in the market; while quality certificate/mark helps to win consumer confidence in the firm's products. Thus the responsible agencies for these institutions, that is, the Uganda National Bureau of Standards (for quality mark) and the Uganda Registration Services Bureau (for intellectual property) need to be engaged more closely as important actors in Uganda's innovation system.

In terms of the human capital potential, it was evident that the investments which firms are making in human resource training is an important factor in enhancing and maintaining a learning environment within firms. Training may be associated with new technologies and ways to handle product improvements and changes in management systems. But given that most firms innovate in-house, the process of learning through experience continues to be an important dimension to the learning process in Ugandan manufacturing firms. Several scholars agree that learning by experimenting, using technology, and interacting is an important aspect of the firm's innovative capacity (Adebowale & Oyeleran-Oyeyinka, 2012; Lundvall, 2010; Lundvall, Joseph, Chaminade, & Vang, 2009; Lam & Lundvall, 2007; Oyeleran-Oyeyinka, 2004). The Ugandan manufacturing firms' practice of spending on training, research and technology is a foundation upon which to build a productive national innovation system. The amounts spent are still small but could be increased gradually over time if, for example, government provided incentives such as tax relief for a certain per cent of the firm's annual expenditure on research and training. And such incentives need to encourage inter-firm cooperative activities and joint projects with local universities and research organizations.

For Ugandan formal manufacturing firms, interaction beyond the firm's inner circles remains a challenge to be addressed. Whereas increased access to internet could support firm's innovative activities, it cannot substitute the inherent value of physical interactions among local actors. But promoting interaction would require addressing firms' concerns with competition and lack of trust among themselves and other organizations. Competition is inherent in any business venture, but it can be managed in such a way that it becomes an opportunity for firms' progress. Competition drives innovation, and innovation helps firms to stay competitive. Firms may collaborate on common issues and technologies that collectively would enhance their competiveness. For example, working together to improve the efficiency of a juice extractor instead of each firm doing it alone, might collectively save time and cost to the firm, and in the end benefit all firms producing juices. According to Walley (2007),firms can simultaneously compete and cooperate, a phenomenon commonly referred to as "coopetition".

However, "coopetition" thrives best where there are reasonable elements of trust. Trust is important in building social relations and networks that promote innovation (Murphy & College, 2002), but the lack of it among manufacturing firms and other organizations in Uganda hinders "coopetition". Better enforcement of contract laws, licensing and intellectual property rights, as well as laws against counterfeit products could help address the issue. Tuunainen and Miettinen (2012) recommend, more specifically for cooperation in research, technology and product development, that firms could use as precaution, secrecy and formal collaborative agreements such as research contracts and memoranda of understanding. However, the use of these measures will require attitude change as most firms seem to be accustomed to informal non-binding (or more commonly "gentleman's") agreement, where the tendency is to locate an individual at the university or local research organization with the desired skill/expertise to do the work on an *ad hoc* basis.

CONCLUSION

The formal manufacturing firms in Uganda, especially in the sub-sectors of food and beverages, chemicals and pharmaceuticals embrace innovation and learning as a necessary undertaking to stay competitive. Most firms' innovative activities are done in-house, a phenomenon which appears common with firms engaged in incremental and adaptive innovations. However, to promote and sustain innovation competence building and competitiveness in the long term, inter-firm collaborations and partnerships with local universities and research organizations should be encouraged. Further research should investigate how these collaborations have or would be developed and work in the Ugandan context, given lessons learnt elsewhere that government, university and industry can work together in a strong symbiotic relationship to promote firm innovations, ensuring that local businesses grow and become more competitive.

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3.5. Paper 4

Biotechnology Developments in Uganda and Associated Challenges

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ABSTRACT

Biotechnology is an important tool whose application Ugandan scientists are exploring in crop, fish and livestock improvement, value addition, waste management, and in medicine. However, the continuing growth of biotechnology or more broadly, biosciences as an enterprise in Uganda will depend on the support given to science and technology generally. To accelerate this growth, Government must ensure supportive science and technology structures such as: a national science funding facility for research and technology development; institutional governance systems which promote innovativeness, and high quality education at all levels to maintain a constant supply of a skilled bioscience workforce. Specific measures at institutional level could include: establishing more synergies between biotechnology programmes and strengthening interactions among the actors both locally and internationally; integrating biotechnology into institutional programmes and regulatory instruments; putting in place technology management policies and developing capacities for their implementation; encouraging private sector participation in commercialization of bioscience innovations, supporting spin-off bioscience-based companies through a national innovation and commercialization fund; and eliminating administrative bottlenecks in procurement and financial management through early and more coordinated planning. This paper gives highlights of biotechnology developments and the associated challenges in Uganda.

Key Words: Bioscience, Biotechnology, Innovation, Policies, Science, Technology, Uganda

INTRODUCTION

Uganda has embraced science, technology and innovation as the cornerstone for economic growth and development (MFPED, 2010). Priority appears to be in promoting science education, research and value addition to bio and agro-based products. The country could have a competitive edge in developing a bio-resource economy given its rich natural resource potential. For this reason, biotechnology is rapidly advancing within the country as a tool to improve crop, livestock and fish production, manage toxic wastes, and develop new materials and improve medical diagnostics and therapeutics. However, the continued growth of biotechnology as an enterprise will depend a lot on how the multiplicity of actors in the field relate with each other, and the foundational support given to science and technology generally. This paper presents key achievements and challenges in biotechnology in Uganda.

HISTORICAL PERSPECTIVE

Avramovic (1996) described biotechnology as "a variety of techniques involving living organisms or their parts as a means of production". Traditionally, baking bread, brewing beer and making cheese and yoghurt employ biotechnology. In this paper, however, biotechnology is closely associated with transgenic organisms or use of recombinant DNA techniques. Biotechnology became prominent in Uganda around 1993 when the Department of Animal Science in the Faculty of Agriculture at Makerere University proposed to test a transgenically derived bovine somatotropin (BST) hormone for growth and milk production in Ugandan cattle. The BST hormone which was to be imported was produced through the genetic engineering of agrobacteria. At the time, the United States of America and the European Union (EU) were deeply engaged in debate over trade on genetically modified organisms. Later that year, in November 1993, the EU placed a moratorium on the sale of BST. In 1995, another proposal was made to conduct a Phase 1 clinical trial of a candidate HIV-1 vaccine (ALVAC vCP 205). The vaccine construct was a live recombinant canary pox vector expressing HIV-1 glycoproteins 120 and 41. It was the first preventative HIV-1 vaccine study in Uganda and in Africa (Cao et al., 2002). The BST and ALVAC vCP 205 vaccine proposals made to Uganda National Council for Science and Technology (UNCST) to a large extent formed the basis for the formulation of national biosafety guidelines, leading to the establishment of a National Biosafety Committee in 1996 (Ssebuwufu, 1998). Later, in April 2008, government passed a national biotechnology and biosafety policy for Uganda. To date, research into biotechnology continues and remains strategic for Uganda. This research ranges from laboratory-based investigations of novel genes conferring resistance to pathogens, drought and other biotic and abiotic stresses, to field trials of transgenic crops, for example, banana, cotton, maize, potato and cassava. Any prospects of moving promising transgenic products to the market require a proper understanding of the constraints and opportunities within the biotechnology innovation system as a whole.

BIOTECHNOLOGY RESEARCH AND DEVELOPMENT IN UGANDA

Biotechnology research and development related work in Uganda is growing (Sengooba & Baguma, 2007; Juma & Serageldin, 2007; Clark, Mugabe, & Smith, 2007). The following are highlights of some of the work:

In agriculture, molecular markers are being used to characterize crop pathogens (e.g. the fungus *cercospora zeae-maydis* which causes gray leaf spot disease in maize and the sweet potato feathery mottle virus). Genetic diversity of crops, and marker assisted selection for viral and disease resistance (e.g. resistance to cassava mosaic disease, cassava brown streak virus and coffee wilt disease) are also being studied. Research is being done to genetically improve East African highland bananas for resistance to banana bacterial wilt, nematodes and weevils as well as to enhance its nutritional value. Confined field trials of bio-engineered bananas which begun in 2007 to confer resistance against black Sigatoka disease caused by the fungus *Mycosphaerella fijiensis* continue at the National Crop Resources Research Institute (NACRRI) near Kampala City. Further, confined field trials of herbicide tolerant and insect resistant transgenic *Bacillus thuringiensis (Bt)* cotton and transgenic cassava resistant to cassava brown streak virus begun at National Semi-Arid Resources Research Institute and NACRRI, respectively. Micropropagation of bananas and pineapples using tissue culture for commercial purposes is being done at Agro-Genetic Technologies Ltd (AGT). The latter is also exploring new protocols for coffee multiplication. In the livestock subsector, identification of drug resistant trypanosome genes is ongoing. Other work include development of animal vaccines and improved diagnostic tools for *Bovine pleuropneumonia*, Newcastle disease, and east coast fever.

In the health sector, molecular markers are being used to study the pharmacokinetics and characterization of drug resistance, especially resistance to anti-malarial drugs, anti-tuberculosis drugs (multi-drug and extremely drug resistant tuberculosis), and antiretroviral drugs for HIV/AIDS. Phase 1 clinical trials of DNA based vaccines developed elsewhere using recombinant adeno 5 virus vector are also ongoing.

In the field of environment, genetic markers are being developed to characterize various species of wildlife including elephants, hippopotamus, buffalo and fish. The results of these studies would be used for conservation planning. A search for and bioengineering of microorganisms to optimize nitrogen removal from heavily contaminated sites is ongoing.

Over the years, organizations in Uganda have developed capabilities for bio-engineering work. Table 3-5 shows capabilities in eight leading organizations in Uganda that carry out biotechnology related work.

Table 3-5: Key biotechnology capabilities in eight organizations

Common Techniques	**Organization**							
	FoAMU	NARLI	NACCRI	MBL	AGT	JCRC	UVRI	FaVMU
DNA finger printing	X	X	X	X		X	X	X
Transformation		X						X
Marker Assisted Selection	X		X					
Tissue culture-micro-propagation	X	X	X		X			
Tissue culture- disease elimination	X							
Tissue culture -germplasm conservation								
Tissue culture-somatic embryogenesis	X	X						
Diagnostics-PCR	X	X	X	X		X	X	X

Diagnostics-ELISA	X	X	X	X		X	X	X
Gene cloning		X	X			X	X	X
Microarrays/Real time PCR	X		X			X	X	
Nucleic acid hybridization		X		X		X	X	X
DNA Sequencing						X	X	
Proteomics						X	X	X

Key

FoAMU- Faculty of Agriculture (became College of Agriculture and Environmental Sciences), Makerere University

NARLI- National Agricultural Research Laboratories Institute

MBL- Med Biotech Laboratories

JCRC- Joint Clinical Research Centre

UVRI- Uganda Virus Research Institute

FaVMU- Faculty of Veterinary Medicine (became College Veterinary Medicine, Animal Resources and Bio-security) Makerere University

HUMAN CAPITAL IN BIOTECHNOLOGY

Systematic efforts to build a critical mass of biotechnology experts in Uganda started in the late 1990s. The East African Research Network for Biotechnology, Biosafety and Biotechnology Policy Development (BIO-EARN) Programme which started in 1998 was one of the pioneer programmes to provide targeted training in biotechnology. The programme initially trained four Ugandans at doctoral (Ph.D.) level in biotechnology related areas through a sandwich between Makerere University and Universities in Sweden. The programme continued to train twelve students at masters (M.Sc.) and two more students at Ph.D. level using the capacity it had developed. Other initiatives such as the Rockefeller Foundation, USAID, and Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) have also made significant contributions in training more human resources in biotechnology. Consequently, modest capacity now exists within the country to supervise biotechnology training at postgraduate levels, provided students can occasionally access more advanced facilities abroad, such as the state-of-the-art scientific facilities at Biosciences East and Central Africa at the International Livestock Research Institute in Nairobi, Kenya. Already, this arrangement for biotechnology training is being implemented by a number of programmes including Agricultural Biotechnology Support Programme of the USAID, BIO-EARN, BiosafeTrain, ASARECA, Regional Universities Forum (RUFORUM), and the Uganda Millennium Science Initiative of the UNCST. Together, these programmes will train locally up to 70 M.Sc. and 20 Ph.D. students in biotechnology related areas by 2012. Biotechnology related work was by end of 2009 being undertaken by a total core scientific workforce of about 200 scientists only, 30% of whom had Ph.D. and about the same number with M.Sc. Technicians and related support personnel comprised the remaining 40% of the workforce. To increase this human capacity, RUFORUM initiated in 2008/09 a new regional postgraduate programme which offers taught Ph.D. and M.Sc. in Plant Breeding and Biotechnology. The post-graduate programme is hosted by Makerere University (in the Faculty of Agriculture, which is now the College of Agricultural and Environmental Sciences).

BIOTECHNOLOGY GOVERNANCE AND REGULATORY ISSUES

Government approved a National Biotechnology and Biosafety Policy for Uganda in April 2008. The policy aims to ensure safe application of biotechnology in Uganda. The policy paves way for use of genetic engineering and related techniques in all fields of science and technology. The specific aims of the policy are to build and strengthen Uganda's biotechnology research and development capacity, promote use of biotechnology in production, provide a sound regulatory framework for bioengineered organisms and promote the ethical and responsible use of biotechnology for national development purposes. There were no specific policies which appeared to hinder biotechnology in Uganda. However, plans are underway to enact a National Biosafety Bill, which is hoped would create a much stronger legal framework for biotechnology in Uganda.

UNCST is the national agency for coordination of biotechnology and biosafety in Uganda. It has over the years developed functional systems for biosafety management of research protocols on bioengineered organisms, and is coordinating the regulation of biotechnology in the country. These efforts resulted in the adoption of the aforementioned National Biotechnology and Biosafety Policy (2008) and the drafting of a Biosafety Bill. Nevertheless, given the cross cutting nature of biotechnology, other regulatory agencies such as the National Drug Authority, the Phytosanitary Inspection Division of the Ministry of Agriculture, Animal Industry and Fisheries, Uganda National Bureau of Standards, and National Environment Management Authority also need to integrate biotechnology and biosafety into their existing regulatory regimes and institutional programmes. These agencies are, by virtue of their mandates, partners in the regulation of bioengineered products and services in the country. It is important, therefore, that they revise and update their regulatory instruments to cover bioengineered products and services as well, and develop specific capabilities for their implementation in this regard.

Public research organizations and universities need institutional intellectual property or technology management policies to protect proprietary knowledge and information, and to allow easy licensing and/or transfer of technology. Such institutional policies facilitate regional and international collaboration and exchange of research materials and information; and the development of partnerships for product development, especially with the private sector. So far, only Makerere University, has an institutional intellectual property and innovation policy which was approved in early 2008. Other universities and research organizations including, for example, the National Agricultural Research Organization, the Uganda Industrial Research Institute, need to establish theirs too.

Administrative inefficiencies in financial and procurement management are emerging challenges public research organizations and universities must address. In 2003, Government enacted the Public Procurement and Disposal of Public Assets Act which prescribes rules and procedures of how public funds ought to be used to acquire goods, works and services. The law aims, inter alia, at ensuring the application of fair, competitive, transparent, nondiscriminatory and value for money procurement and disposal standards and practices by public agencies. This procurement law is not, however, well understood by most scientists, and many public organizations still struggle with its implementation. As a result, there have been inefficiencies in procurement, leading either to delays in acquiring goods, works and services or scientists not getting items with the right specifications for their work. In so far as most research is externally funded, and even when locally financed, proper accountability for funds and more efficient procurement management are paramount in sustaining research collaborations, and ensuring timely and high quality scientific work. Therefore, early procurement planning and timely procurement are necessary, and the scientists themselves as users must be involved in the procurement process.

INTERACTIONS AMONG BIOTECHNOLOGY ACTORS

In Uganda, key actors in biotechnology research and innovation are in the public research organizations and universities, mainly Makerere University and the National Agricultural Research Institutes. The actors somehow know each other, but not so much about what each one is doing. Interactions among them are generally weak and very informal, as it depends on the initiative of an individual scientist. Interactions with the private sector are even much weaker, although it is common to find active scientists/ researchers in the public sector who make reasonable effort to collaborate with private organizations -firms, farmers and non-Governmental organizations. Firms are often reluctant to reciprocate because they tend to focus more on immediate results and short term financial gains (salary and allowances). It is, therefore, difficult to trace a true symbiotic relationship between public sector scientists and entrepreneurs in the private sector. However, collaborations between local scientists and their counterparts abroad appears to be stronger, perhaps because foreign partners have more advanced scientific facilities which the local scientists can access periodically. Partners abroad also provide training opportunities for local scientists to enhance their skills, and are also seen as a gateway to international research funding sources. In this regard, it is important that Ugandan scientists develop and nurture strategic international science and technology partnerships to support growth of the biotechnology enterprise in Uganda. In all, interactions among local biotechnology actors in Uganda as well as with their counterparts abroad need to be strengthened. One way would be to have more "bio-2biz" type of fora focusing on enterprise development opportunities arising from bioscience innovations in the public research organizations. The aim of such fora would be to seek collaboration with partners at the outset of research and to identify partners in product development and dissemination. These would be complimentary forums to ongoing initiatives such as the Open Forum for Agricultural Biotechnology (OFAB) which was established in December 2007 through partnership between UNCST, International Food Policy Research Institute's Program for Biosafety Systems, and the African Agricultural Technology Foundation headquartered in Nairobi, Kenya. The OFAB is a monthly luncheon organized by UNCST which brings together scientists, policy makers, media and the public to discuss topical agricultural biotechnology related issues globally and nationally.

FINANCING BIOTECHNOLOGY

A larger proportion of biotechnology work in Uganda is funded from abroad. Most of the financing comes through research collaborations, and draw from competitive grants in the international community. The major sponsors of biotechnology work in 2009 were: Swedish International Development Agency (Sida) through the BIO-EARN Programme and the bilateral research collaboration program between Makerere University and Swedish universities, USAID, Rockefeller Foundation, Bill and Melinda Gates Foundation through the Alliance for a Green Revolution in Africa (AGRA), ASARECA, Monsanto and Government of Uganda through the Uganda Millennium Science Initiative (MSI) project. A sustainable national funding mechanism for research and technology development is required in Uganda. Government should establish a national science funding mechanism which is predictable, transparent and merit based, and which makes grants for research and technology development available annually both directly and on a competitive basis. This dual financing arrangement for research and innovation is not new. Countries with a true commitment to advancing science and technology as an engine for economic growth and development have established their own national science funding agencies. South Africa, for example, has the National Research Foundation and United States of America has the National Science Foundation. Countries like these compete favourably in the international market, because their industry and commerce is backed by science and technology strategically financed from domestic sources. In Uganda, an emerging good example would be the MSI which in 2007, 2008 and 2009 awarded several large grants on a competitive basis to support research, innovation, and science curriculum development. This type of funding allows for training of more scientists, equipping research facilities, and can sustain longer term research and innovation programs in organizations, including enlarging employment opportunities for scientists. Government can build on the success of its MSI, and allocate more resources to it so that grants are awarded annually to productive research groups. It is estimated that Government contribution of approximately US dollars five to eight million annually to the MSI type of funding in the medium term would support implementation of more than 50 large research programmes with at least 250 scientists participating in any given year. In this way, scientists would be motivated to think creatively and innovatively all the time, because they would be assured, somehow, of a possibility of getting funding for their projects. It is also an incentive to retain highly skilled scientists in the country and to attract those in the Diaspora. Further, it is arguably the most appropriate way to support and sustain bilateral cooperation in science and technology and joint research activities. By adopting such dual financing for research and innovation, government can tap the real potential of Ugandan scientists to contribute to economic growth and national prosperity. Additionally, some type of "bridging finance" would be needed. That is, small amounts of money which would facilitate the crucial product development phase of an innovation, moving the innovation sufficiently along the product development pathway for it to become of interest to potential private partners. Such funding would be provided through a microcredit scheme or as alluded to above through an innovation fund such as the existing Presidential Support to Scientists fund, and the Uganda MSI grants for technology platforms.

PRIVATE SECTOR INVOLVEMENT

Private bioscience-based enterprises in Uganda are yet to evolve. Public research organizations will for some time be the major players in biotechnology research, product development and dissemination. However, government can encourage private commercialization of bioscience innovations by supporting spin-off bioscience-based companies. Spinoffs would have an added advantage of attracting more technically skilled workforce into private sector. However, for a start, Government could provide venture capital for innovation and commercialization of research products independently or through the Uganda Development Corporation, to interested scientists who would like to start a bioscience based enterprise. Government has to intervene because there are no private venture capitalists in the country as yet for bioscience-based innovations. Furthermore, private sector could be deliberately supported to exploit business opportunities that arise from innovations in public research organizations. Public research organizations should not only focus on directly commercializing their innovations; but they may also, through well-established technology management policies, license these innovations to the private sector.

CONCLUSION

The biotechnology or more broadly, biosciences enterprise in Uganda is growing, but this growth is dependent on the foundational support given to science and technology generally within the country. Strong supportive science and technology structures are needed. These include: a national science funding facility for research and technology development; institutional governance systems which promote innovativeness; and high quality education at all levels to maintain a constant supply of a skilled scientific workforce. In addition, public research organizations in Uganda need to play a more active role in forging the links which are essential for innovation.

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3.6. Paper 5

A Technological Innovation Systems Perspective on the Shea Butter Enterprise in Uganda

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ABSTRACT

This paper analyses the emerging Shea butter enterprise in east and northern Uganda from a technological innovation systems perspective. It describes the structure of the innovation system for Shea butter and its associated products, how the system is functioning and the underlying policy issues affecting growth of the Shea butter enterprise in the region. Data was collected by interviewing 20 key informants in the Shea districts, five focussed group discussions with farmers group leaders, processors, local government officials, private sector and development aid practitioners, and by observing Shea butter processing in firms. Findings reveal that Shea butter production and processing is very much a cottage enterprise supported by women groups, but has potential to evolve into a dynamic business cluster. Actors and institutions that could support the enterprise exist, but in isolation of each other. There was evidence of new Shea butter business entrants, but continued growth of the enterprise will depend on the extent to which the actors, particularly local governments, universities, private businesses and the community are willing to interact and learn from each other. These findings point to the potential critical role that knowledge actors like universities and research organizations could play in supporting community initiatives and local business enterprises.

Keywords: Community, Enterprise, Innovation system, Shea butter, Uganda

INTRODUCTION

From time immemorial, communities in east and northern Uganda (who numbered about 25 percent of the total population in 2002) have used Shea butter from the tree *Vitellaria paradoxa* (the Shea tree) for food, cosmetics and medicine. Women and children gather ripe Shea fruits from the wild, eat the minerals, proteins and vitamins-rich pulp, and keep the kernels (Maranz, 2004). Shea butter/oil is extracted from the kernels and used to flavour food. The oil is also used to smear new borne babies, and to relieve muscle aches and soothe the skin. Clinical studies have shown efficacy of Shea butter as nasal decongestant (Tella, 1979). Nectar from Shea tree flowers attract honeybees and birds in large numbers (Dukku, 2010), which pollinate farmers' crops and provide honey for the community. Traditionally, mortars and pestles (indispensable household tools in this community) are made from the hard wood Shea tree. The Shea tree is endemic to this part of the country, extends to southern South

Sudan and stretches about 5000 kilometres to Senegal in West Africa (Chalfin, 2004; Okullo et al., 2010). The trees grow in the wild, mature and start fruiting at 15-20 years, and continue to fruit for nearly 400 years (Ferris, Collinson, Wanda, Jagwe, & Wright, 2004). Because of these unique and valuable attributes, communities in northern Uganda say, 'Shea tree is a gift from God!' Recent studies have confirmed the immense traditional values communities attach to the Shea tree and Shea butter (Gwali et al., 2011) .

The value of Shea butter is widely acknowledged, but has not been translated into tangible economic benefit for the communities in east and northern Uganda. Of recent new micro and small scale enterprises have emerged, introducing new methods (cold press) for producing Shea butter. The enterprises also produce a variety of novel Shea butter based products like soap, cosmetics and ointments. However, they are not organized with a shared strategy for investing in Shea butter production and value addition. How knowledge and technology could be harnessed to create greater value in the Shea butter enterprise in this community was less understood. This paper identifies key policy issues in the development of the Shea butter enterprise in Uganda and the region using a technological innovation systems approach. The paper focuses on the diversity of actors interacting in different ways in the production, processing and value addition of Shea butter. The emerging structure and dynamics of a Shea innovation system is described, as well as the factors affecting Shea butter production and value addition.

The technological innovation systems (TIS) approach draws from earlier works of Christopher Freeman, Bengt-Ake Lundvall and Richard Nelson and other scholars who consider it a useful approach to understanding the barriers and enabling conditions for growth and competitiveness of enterprises (Lundvall, Joseph, Chaminade, & Vang, 2009; Edquist & Johnson, 1997). The innovation system concept is defined by relationships within and between organizations, and how these relationships eventually lead to innovations and competence building (Lundvall, 2010). Learning is a central activity in any innovation system. Therefore, formal educational organizations including schools, colleges and universities, are essential for the system to function well. But equally important is the learning that takes place in non-formal settings through apprenticeship or by using a product or service, where knowledge is gained through experience, practice and sharing (Lundvall, 2010; Oyelaran-Oyeyinka, 2006).

The TIS approach adopted in this paper is based on the framework suggested by Bergek et al. (2008). It is a framework for analysing innovation systems in terms of their functions, and usually revolving around diffusion in society, at various levels, of a technology, product or process (Bergek et al., 2008). In this paper, the focus is on Shea butter and its derivative value added products. Table 3-6 is a summary of Bergek et al's framework, specifically presented in relation to Shea butter.

Table 3-6: Functions of technological innovation systems (Shea butter)

Function	Description
1. Knowledge development and diffusion	The breath of scientific, traditional and local knowledge, in this case, on Shea butter production, processing and value addition;
2. Influence on the direction of search	Factors which make investment in Shea butter attractive, including incentives, policy preferences, new markets, etc.
3. Entrepreneurial experimentation	Emerging entrepreneurial activities, for example, new firms venturing into Shea production and value addition, the range of products and processing methods employed.
4. Market formation	Trends in the development of the Shea butter market, type of the market (nursing, bridging, mature), potential size of the market, and what is generally driving the formation of this market;
5. Legitimation	General perception about Shea butter and its products, and acceptability by the community and other actors.
6. Resource mobilization	Resources that are available, e.g. financial, human, and other complimentary products or services for Shea butter production and value addition;
7. Development of positive externalities	External economies brought about by the performance in the above functions--political support, advocacy coalitions, etc.

METHODS

A combination of qualitative research techniques were used, including focused and open ended interviews; focus group discussions, observations, and review of policy and related documents. Verbal consent of individuals were obtained for all interviews and focus group discussions. Questions and topics discussed were related to the respondent's knowledge or experience in Shea butter production and relationships with other actors in the enterprise. The respondents were purposively selected based on their work with Shea butter.

Seven Shea butter producers were visited in the Shea districts of Soroti, Lira, Pader, Otuke and Moyo. Shea butter production process was observed in three firms, although the process was also explained at each firm visited. At each firm a focused interview was held with either the owner of the firm, or a senior staff heading the production unit. The firms were located by referral from individuals in the community and other firms earlier met.

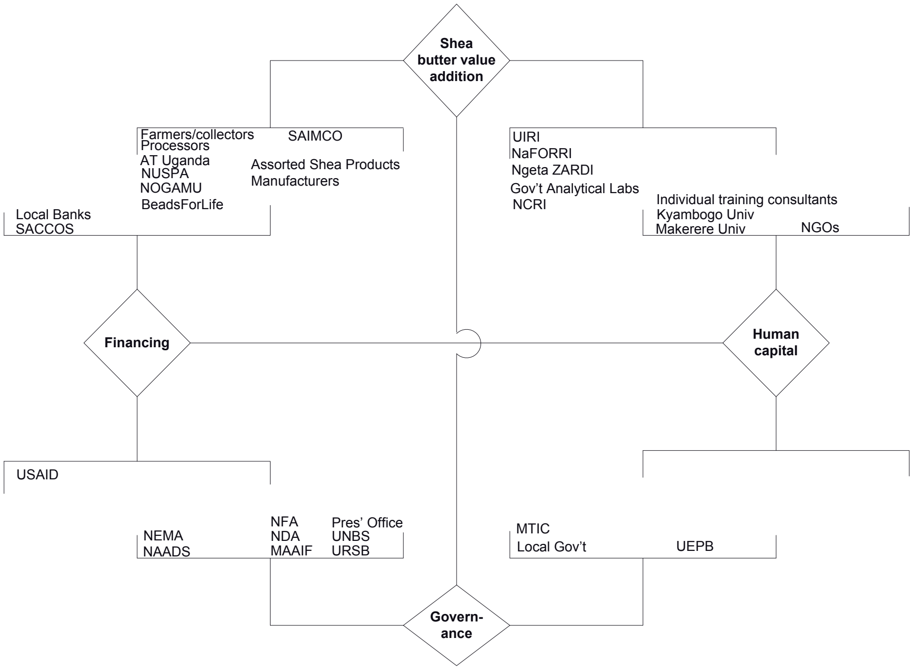
Four focussed group discussions were held with representatives of farmers groups involved in Shea collection in each of the Shea districts of Moyo, Agago, Otuke and Amuria. Another focus group was held in Kampala (Uganda's capital city) involving processors, scientists, finance specialists and development aid workers. Each focus group discussion was attended by seven to 12 participants. Three homes of Shea kernel collectors were visited in Moyo, Amuria and Agago districts to observe how Shea kernels are collected and stored, and how the trees are protected in the gardens.

Furthermore, a total of 20 local government officials were interviewed in all the Shea districts regarding local government policies and plans for Shea butter production. These officers included District Forest Officers, District Commercial/Production Officers, District Administrative Officers, and Local Council III Chairpersons. An official from a local Non-governmental organization in Lira, two officials from two public research organizations, and one official from an international Shea processing plant were also interviewed. A firm which makes Shea butter processing machines in Soroti was also visited. Data was transcribed and analysed.

RESULTS AND DISCUSSION

Structure of the Shea Innovation System

First, the structure of the Shea innovation system in east and northern Uganda, that is, the actors, networks and institutions involved in Shea butter production and value addition are given in Figure 3-14. The structure consists of four parts: a) activities directly related to Shea butter production and value addition in Uganda, b) how the activities are financed, c) how they were governed in terms of policy and regulations, and d) how human resources and skills were organized and provided. Here, 'value addition' includes all activities aimed at increasing Shea kernel yields, improving postharvest handling, and scaling up Shea butter production, design and manufacturing of Shea butter products like edible oil or fat, soap, ointments, cosmetics and other skin care products.



Acronyms
URSB-Uganda Registration Services Bureau
NEMA-National Environment Management Authority
NDA-National Drug Authority
UNBS-Uganda National Bureau of Standards
NAADS-National Agricultural Advisory Services
Pres' Office-President's Office
NFA-National Forestry Authority
MAAIF-Ministry of Agriculture, Animal Industry & Fisheries
UEPB-Uganda Exports Promotion Board
SACCOS-Savings and Credit Cooperative Organizations
NOGAMU-National Organic Manufacturers in Uganda
NUSPA-Northern Uganda Shea Processors Association
SAIMCO-Soroti Agricultural Implements and Machines Company
UIRI-Uganda Industrial Research Institute
NaFORRI-National Forestry Resources Research Institute
NCRL-Natural Chemotherapeutics Research Institute
Ngeta ZARDI-Ngeta Zonal Agricultural Research & Dev't Institute
NGOs-Non-Governmental Organizations
MTIC-Ministry of Trade, Industry and Cooperatives

Figure 3-14: Actors and their roles in the Shea butter production and value addition

Shea Butter Production and Value Addition

Shea butter is produced from kernels left after eating the Shea fruit pulp. The fruit is harvested in May through August every year (Okullo, Hall, & Obua, 2009). Harvesting is usually done early in the morning by women and children. The pulp is eaten, and the kernel is sun dried and stored. Yields of 15 to 55 kilograms of fresh fruit per tree have been reported in literature (Ferris et al., 2004).

Women process some of the kernels into oil for household consumption. First the dry kernels are cracked with a hard object (wood or stone) to remove the outer shell. It is then put in sand in a large saucepan or pot and roasted. After roasting to dark colour, it is left to cool. The roasted kernels are ground to fine paste, and boiled with water in a pot or saucepan. After some time, a light yellowish liquid (oil) is decanted into clean vessel, ready to be eaten or used as baby oil. Local communities report a shelf life of up to two years for Shea oil produced in this way.

Other kernels are sold in the market or to local Shea butter producers. Most of them cottage firms, that is, small family owned processing units in the backyard of homes in trading centres or small towns. The exact number of Shea butter producing firms and cottages is unknown. By the time of this study only one, small scale firm (Guru Nanak Oil Mills) in Lira Town was known to produce Shea butter at factory scale; but even then, only as a very small fraction (approximately one tenth or less) of its oil products. A substantial amount of Shea butter is produced by the wider community using the traditional method. Shea butter produced traditionally is mainly for household consumption; a little bit of it is sold in local markets. Usually middlemen buy kernels and sell to producers of Shea butter. Some producers buy directly from organized women or farmers' groups. In which case, the producers would normally organize and establish their own groups and enter a contract with them to buy/supply Shea kernels. A group may be up to 50 women. Besides Shea collections, the groups also deal in other commodities. In a good harvest season, each group member reportedly on average may collect more than 100 kilograms of Shea kernels. Each kilogram of kernels cost up to US$ 0.6 at the end of 2011.

Producers buy the kernels and sort them into three grades A, B and C according to size, moisture content, and breakage. The cold press method is used to extract Shea butter from the kernels. In this method, the kernels are cracked manually to remove the outer shell, and then ground to fine paste using a motor operated grinding/crushing machine. The machines are powered by electricity or most commonly by diesel generators. After grinding, the paste is put in the oil pressing machine and pressed. The resultant light yellowish liquid, Shea butter, is collected in a dry container ready to be used. It is commonly packaged in plastic containers of various sizes and sold as a raw material for the manufacture of other value added products such as ointments, hand and body lotions, hair creams, baby jellies, soap, and other skin care products. In most cases Shea butter producers also ventured into making Shea butter value added products, especially cosmetics and soap. Producers report a shelf life of two years. The left over Shea cake is removed and discarded as waste. Some local producers report the cake repels mosquitos. No commercial or other use of this waste by product was reported. Although, local production is beginning to take root, an unspecified amount of Shea kernels are also exported and processed abroad.

The cold press machines are manufactured locally, notably by Soroti Agricultural Implements and Machines Company, located in one of the Shea districts, Soroti. One local artisan in Lira Town may also be able to fabricate the machine. Some machines are, however, imported from India or China. Each complete unit manufactured locally cost Uganda Shillings three to five million (approximately US$ 1200 to 2000).

Bridging organizations helped to organize women groups and producers. They also assisted with machine acquisition and marketing of Shea butter. For example, the

Northern Uganda Shea Processors Association (NUSPA) supported Shea producers with machines for cold press and assisted in marketing the Shea butter. NUSPA was formed in 1996 by a United States Agency for International Development funded Shea Project for Local Conservation and Development (COVOL), later becoming a cooperative society. However, when COVOL project scaled down in 2008/9, NUSPA ceased to be active. Another organization, the National Organic Agricultural Movement of Uganda (NOGAMU) also promoted the production, processing and marketing of organic Shea butter. NOGAMU and NUSPA were instrumental in having national standards for Shea butter set by the Uganda National Bureau of Standards. Other notable actors were BeadsforLife and Appropriate Technology (AT) Uganda. These non-governmental organizations bought and helped market Shea butter from the communities and local producers.

A number of public organizations were involved in research with Shea butter. Some of these organizations included Uganda Industrial Research Institute which developed some value added products from Shea butter, Makerere University and National Forestry Resources Research Institute which carried out research on physico-chemical characteristics of Shea butter and ecology of Shea trees, Ngeta Zonal Agricultural Research and Demonstration Centre which was used to experiment with grafted Shea trees, Government Analytical Laboratories and the Natural Chemotherapeutics Research Institute collaborated in carrying out quality tests on Shea butter samples.

Financing of Shea Butter Value Addition

As Figure 3-14 shows, financing for Shea butter value addition was predominantly by individual firms, especially firms manufacturing Shea butter value added products. Cottages financed Shea butter production with income from other businesses or jobs, since most of them were not exclusively in Shea butter trade. Occasionally, bridging organizations like NUSPA, BeadsForLife, AT Uganda, and NOGAMU provided financial support. In a few instances, communities of collectors formed Savings and Credit Cooperative Organizations to finance their activities. Banks offered financial services, and sometimes micro credit for Shea butter production. In the mid-1990s, USAID through COVOL project provided financing for Shea butter processing in the region. COVOL operated in almost all the Shea districts of Uganda, providing implements, training, and helping establish farmer groups for Shea kernel gathering. However, after COVOL scaled down its operations, a number of the initiatives stalled. Some of the then COVOL employees established their own cottages for Shea butter production.

Governance of Shea Butter Value Addition

Governance issues were concerned more with the conservation status of the Shea tree. Being a hard wood tree species, the Shea tree makes good charcoal. Charcoal burning is a serious threat to the Shea tree. In some districts like Soroti and Lira, the Shea tree is almost depleted due to charcoal burning and clearing land for farming. Charcoal burning became the main source of income for the region which was recovering from two decades of civil unrest and the brutal Lords' Resistance Army rebel insurgency.

Government has listed the Shea tree as endangered, and through local government councils, passed bye-laws banning the cutting of Shea trees for charcoal. Enforcement of the bye-law was still weak, but it was welcomed by some local community members who said it reminded them of their old traditional sacred beliefs which prohibited cutting of Shea trees. They believed that the Shea tree is a divine gift and anyone who cut it would be cursed.

In a lot of places, individuals and families took initiatives to preserve Shea trees in their gardens. They prevented unauthorized felling of the tree for charcoal. It was easy do so where land was privately owned. But where land was communally owned (as is the case in most parts of the Shea districts), one had to convince other relatives to recognise the value of preserving the Shea tree. Those who took such initiative acknowledged that the long term benefit from preserving Shea trees was much better than the short term gain from cutting the tree for charcoal. The communities were aware of the importance of the Shea tree in attracting bees which pollinate their crops and gives them honey, as well as manure for their soils. A local community member remarked during an interview:

> *'This tree (Shea tree) is very important because it provides oil, and even when it has flowered…that is where bees go and collect nectar; and its honey is very nice—when you eat, that odour which you smell…'*

In 2006, the President of Uganda issued a directive to protect the Shea tree from overexploitation. The President also directed that a factory for Shea butter production be established in the region. In response partly to this directive, the National Environment Management Authority prepared a draft National Strategy on Shea aimed at promoting sustainable utilization of the Shea tree. The Uganda Exports Promotion Board also included Shea butter as biotrade product to be promoted; while the Uganda National Bureau of Standards developed National Standards for Shea butter; and had an on-going certification scheme for small businesses, which Shea producers could benefit from.

Human Capital Development

The human resource capacity for Shea butter exploitation existed, but it was latent. Most of the Shea butter producers were schooled individuals with formal education: certificate, diploma or degree certificates. However, majority of them operated cottages as a side business. Extremely few cottages hired full time employees. Those working in the cottage firms had either formal or informal learning from their previous employment. There are no specialised training programmes in Shea butter production and processing. However, some work was done by undergraduate and postgraduate students from Makerere University and Kyambogo University. The students' work was mainly on the processing methods, physico-chemical characteristics of Shea butter, and ecology of the Shea tree. Occasionally non-governmental organizations hired private consultants to train and provide skills in postharvest handling of Shea kernels and processing of Shea butter.

FUNCTIONALITY OF THE SHEA INNOVATION SYSTEM, POLICY ISSUES AND RECOMMENDATIONS

The functional elements within the Shea innovation system are discussed here using Bergek *et al*'s framework (Table 3-6).

Knowledge Development and Diffusion

Shea butter has been studied quite extensively especially in West Africa. Carney & Elias (2006) have traced the earliest records on Shea butter to the 13th century when it was traded for salt and fish from the West African coast, and by Muslim travellers along trade routes in the Sahara. European explorers, notably Mungo Park in the 1790s, made the first recorded descriptions of Shea butter, and how it was processed traditionally (Carney & Elias, 2006). By the 1920s Shea butter was traded between West Africa and Europe as a raw material for margarine and candles (Ferris et al., 2004). Recent studies have focused on the ecology of the Shea tree, its natural regeneration and propagation by farmers (Okia, Obua, Agea, & Agaro, 2005; Orwa, 2009; Sanou et al., 2004). Other studies by the National Forestry Resources Research Institute plan to develop fast maturing and better yielding varieties of the Shea tree. These studies and the Shea projects by non-governmental organizations, helped highlight the importance of Shea tree in the livelihoods of communities in the Shea districts. However, there were no mechanisms to further these studies beyond the academic interests of the students.

Physico-chemical characteristics and fatty acid profiles of Ugandan Shea butter show that is it a high value vegetable oil (Okullo et al., 2010; Honfo et al., 2010; Maranz, Wiesman, & Garti, 2003). These studies have shown important differences in the West African and East African varieties of Shea butter. A key difference is in the fatty acid profiles. The West Africa variety (*Vitellaria paradoxa sp paradoxa*) has more stearic acid, which makes it a good cocoa substitute in chocolates; while the East African variety (*Vitellaria paradoxa sp nilotica*) on the other hand is richer in oleic acid, which makes it a good moisturizer. The Ugandan Shea butter therefore would find greater use in cosmetics, edible oil, soaps, and other skin care products. Firms in Uganda have developed some of these products, but they have not tested them to ascertain their efficacies and to compare quality with other similar products on the market. More research and product development is needed for novel formulations and product blends, design and testing of Shea butter products.

Communities in the Shea districts have used the traditional method of producing Shea butter for decades; and more recently cottage firms have adopted the cold press method. However, efficiency of these methods has not been fully studied. In order to close this gap, firms and local artisans should explore possibilities of collaborating with knowledge centres, like universities and local research organizations, to optimize production efficiencies.

Influence on the Direction of Search

Main drivers for investment in Ugandan Shea butter seem to be the anticipated growing global markets especially for Shea butter derived cosmetics and other skin care products. Ugandan Shea butter is promoted as a good moisturiser because of its higher oleic content. It is also promoted as an organic product because it grows naturally and is collected in the wild. However, it means that if firms are to meet the certification requirements for organic Shea butter, the kernels must be collected from farmlands where no pesticides or herbicides have been used. In other words, farmers who wish to trade in organic Shea kernels should neither spray their crops nor apply fertilizers in their fields. Use of fertilizers and agrochemicals is generally low in Uganda (less than 0.6kg/ha), but may rise as farmers begin to grow more commercial crops like maize and sunflower (Ministry of Agriculture Animal Industry and Fisheries, 2010). When this happens, it may pose a challenge in sustaining the organic Shea market.

Shea butter production may also be promoted as a strategy to supplement household incomes in the Shea districts which are recovering from two decades of tyranny of the Lord's Resistance Army rebels who had displaced over one million people from their homes between 1986 and 2006. As communities return to their settlements, diversified sources of income become necessary for households, particularly for the women. In this regard, investing in Shea butter production may contribute to inclusive growth in the region, given also that Shea butter has received the global Fair Trade certification (Fair Trade Foundation, UK) (Greig, 2006). Fair trade is a global social movement which advocates for fair trading conditions for disadvantaged producers and consumers so that the latter can extricate themselves from poverty and have a sustainable livelihood. Fair trade arrangements offer premium prices for farmers and helps cushion them from fluctuations in the global markets.

A great opportunity for Shea butter investment in Uganda, however, comes from the good political will towards Shea butter production. The President's directive of 2006 to build a Shea butter processing factory in the region is a good example. This directive has not yet been implemented. The holistic strategy for sustainable utilization of Shea in Uganda proposed by the National Environment Management Authority aims to support conservation of the Shea tree, marketing of Shea butter, research in Shea and promotes capacity building, collaboration and coordination. A key challenge, however, will be to ensure that all actors actually engage and interact in a manner that promotes learning and innovation. It seems that the strategy would add greater value if it focused on innovations from Shea butter as its locus, in order to enhance collaboration and cooperation among the actors.

Entrepreneurial Experimentation

Shea butter production in Uganda is still very small compared to West Africa (Ferris et al., 2004), and very much a cottage and community activity. Most cottages and firms emerged in the last five to ten years. Most of these cottages are engaged in Shea butter production using the cold press method, and also in very small scale manufacturing of Shea butter cosmetics, soaps, and ointments. There is no organized marketing of these products yet. The products are usually sold through networks of friends and families. This may be partly because the industry itself is not organized, and firms and cottage owners and employees lack entrepreneurial skills. Trade secrecy characterises much of the marketing of Shea butter and its products in Uganda.

Market Formation

Global demand is projected to rise as Shea butter is increasingly recognized for its superior properties in making beauty and skin care products, and, in the case of West Africa Shea butter, as cocoa substitute in chocolates (Elias & Carney, 2007). However, to penetrate both local and international markets, local Shea butter producers and processors, may need to work towards certifying their products for safety and quality. The National Drug Authority is capable of certifying safety of cosmetic and medicinal products; and a quality mark can be obtained from the Uganda National Bureau of Standards. Also, by registering their trademarks with the Uganda Registration Services Bureau, local producers of Shea butter and manufacturers of value added Shea butter products may have greater control of their markets.

Within Uganda, the tax regime is favourable for locally manufactured goods and for Ugandan exports. All exports of goods and services is zero rated (Government of Uganda, 2005). This along with other incentives such as the liberalized foreign exchange market and availability of land for investors could promote investment in Shea butter production and processing.

Legitimation

As a product traditionally consumed and used for decades, Shea butter is acceptable in the Shea districts and communities. Its use as a food flavour is common only among communities in the Shea districts. But some people, especially those outside the Shea districts, find the flavour quite strong and unpleasant (personal communication). Possibilities of blending with fragrant perfumes and other mechanisms to suppress the smell could be explored when promoting Shea butter as cosmetic. However, its fragrant smell especially when traditionally processed is what makes it a delicacy for the communities that consume it this way. This point was emphasised by one of the focus group participants who said,

> *'…the traditional method of producing the oil we may think produces oil with a bad smell, but that smell makes it what it is, and when you remove the smell, it ceases to be commercialisable among the people who know it….therefore, we should promote both technologies which remove the smell and also retain it.'*

Resource Mobilization

Shea butter production using the traditional method is an art which can be easily learned and perfected with time. About one in ten households in the Shea districts are capable of producing Shea butter using the traditional method. Similarly, the conventional cold press method can be easily mastered and perfected with time. Therefore, the necessary human resources for Shea butter production cannot be in short supply. However, expertise may be required to optimize production processes, and to design and develop Shea butter value added products. This expertise and the infrastructure for quality testing and assurance can be available in the private sector as well as the universities and local research organizations, and could be reasonably afforded at prevailing labour market rates. This notwithstanding, there is an untapped potential in the three public universities located in the Shea districts: Busitema University College of Agricultural Sciences in Soroti, Muni University in Arua, and Gulu University of Agriculture and Environment Sciences in Gulu. There are also public agricultural research organizations in the region viz, the National Semi-Arid Resources Research Institute in Serere district and Ngeta Zonal Agricultural Research and Development Institute in Lira, among others. These are potential knowledge providers all within reach in the region and could possibly make a significant contribution to the development of the Shea butter enterprise in east and northern Uganda. To begin with, these universities may need to learn from the experience of Makerere University in creating and working with innovation systems and business clusters.

Most of the investments in Shea butter production and value addition are financed by Shea producers themselves through savings and micro credit. Of recent some financial opportunities were put in place which could support farmers, women groups and small firms involved in Shea butter business. For example, the Youth Entrepreneurship Venture Capital Fund set up by government in 2010/11. Under this scheme a youth can access up to US$ 2000 to support his/her business, while a group of five youth can access up to US$ 10,000 for a joint business venture. Another useful scheme is the Agribusiness Initiative Trust (aBi) set up in 2010 by development partners and led by Government of Denmark and Uganda. The aBi offers financial services and technical support for private sector driven agribusiness development ventures. Oil seeds is one of the value chains eligible for aBi support. However, red tape in accessing these financial services may be a limiting factor for the majority of individuals and small firms engaged in Shea butter production and processing.

Another concern may be that, whereas financial services are being created to support private sector initiatives, there is no clear mechanism to link this support with potential contribution from the knowledge actors such as local universities and research organizations. If Shea butter productivity should increase, local governments, universities, research organizations and Shea producers should be closely linked. It has been demonstrated that innovations thrive and more value is created where universities, industry and government effectively collaborate (Etzkowitz, 2003).

Development of Positive Externalities

The Shea butter industry in Uganda is still very small. Although the value of Shea butter is widely recognised, no real investments have yet been made to fully exploit it. Suffice to say, however, that this recognition of Shea butter as a high value product made local governments pass bye-laws to conserve the Shea tree. But other than the bye-law, local governments of Shea districts have not prioritized Shea butter as a potential investment opportunity. These local governments need to include Shea butter production in their district development plans.

CONCLUSIONS

The Shea butter enterprise in Uganda is still very much a cottage and community undertaking. Therefore, the participatory involvement of the local community and especially of women is critical for its success. Though the annual per capita returns from Shea kernel collection may be small at individual level, it supplements household income. At an aggregate regional level returns to investment on Shea butter production and processing could be enormous. Therefore, the real motivation and incentives for the community to conserve the Shea tree and sustain the supply of kernels for Shea butter production may be a combination of the intrinsic ecological and traditional values they attach to the Shea tree, their need for supplemental incomes and the wider social value of Shea butter to the global community. The appreciation of this wider social benefit which comes from aggregate collection of kernels and processing of Shea butter will be critical for growth of the Shea butter enterprise in the region. Furthermore, in order to boost Shea butter production, the support of the local governments in the Shea districts is essential. Local governments should first and foremost include Shea butter production and processing in their district development plans as an overall development framework for collaboration among the actors.

It appears from a technological innovation system perspective that the essential ingredients for a vibrant Shea innovation system are in place, that is, the organizations and institutions. But these need to be organized in a manner that promotes interaction and learning among key actors like local governments, the universities and other knowledge centres, private businesses and the community. In this way, collaborative partnerships may emerge for addressing common challenges such as machine inefficiencies, poor product quality and marketing, while ensuring that individual businesses grow and become more competitive. This type of arrangement may result in good outcomes for the Shea butter enterprise and eventual growth of Shea cluster firms in the region.

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3.7. Paper 6

Cluster Development in Low Resource Settings: The Case of Bioethanol and Fruit Processing Clusters in Uganda

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ABSTRACT

Innovative clusters are being adopted in low income countries. The challenge is to make them grow to become competitive. This paper identifies enabling conditions and barriers to the growth of two clusters in Uganda viz: bioethanol and fruit processing clusters. A technoscientific[2] innovation systems approach with a specific technological innovation systems analytical framework is used. The clusters were taken as sectoral innovation systems. In each cluster, focus group discussions with cluster firms and interviews were held, cluster activities were observed, and relevant documents were reviewed. Findings reveal that active participation of university scientists in the clustering process is an enabling factor, especially when they maintain a significant presence in the cluster communities. The clusters, however, need to be more inclusive of other actors including financial institutions, business associations, farmer groups, inputs suppliers and relevant non-governmental organizations. The absence of targeted goals and incentives specifically to attract investments in the cluster areas and to drive formation of markets for the cluster products is a major barrier. However, the goals, if formulated, should balance promotion of cottages[3] with developing more larger-scale industrial enterprises. This work shows that it is possible to use a technoscientific innovation systems approach to identify and address cluster development challenges in low resource settings, taking into account unique socio-economic and cultural issues.

Key words: Bioethanol, Cluster, Fruit Processing, Innovation System, University, Uganda

INTRODUCTION

Cluster development is widely regarded as one of the ways of ensuring competitiveness of firms and accelerating industrial and economic growth (Brakman & Van Marrewijk, 2013; Mwamila & Diyamett, 2011). A cluster is a concentration of firms in a geographic region that are interconnected by the market they serve and the products they produce, as well as by the suppliers, trade associations, and educational institu-

[2] This approach is based on the understanding and experiences of triple helix, mode 2 (Nowotny et al., 2001) as well as of Donna Haraway and her situated knowledges (Haraway, 1991)

[3] Jaffe and Azumi (1960) used the term cottage industries to include economic activities except agriculture, which are carried out on, at, or near the home of the worker. This also includes small-scale retail trade carried out on, at, or near the home of the proprietor by the members of her/his family (Jaffe & Azumi, 1960).

tions with which they interact (Colgan & Baker, 2003). According to Porter (2000), clusters 'represent a new way of thinking' about economic growth at all levels, but which requires new roles for companies, government agencies, universities and other organizations in enhancing competitiveness.

The cluster concept is relatively new in Uganda. Typical cluster initiatives started to be promoted in Uganda and in most of eastern Africa around 2004, mainly by proactive university scientists, who view it as a collaborative platform between universities, industry and government (Mwamila et al., 2004b). This effort led to the creation of the Makerere University-led Innovation Systems and Clusters Programme (ISCP-Uganda), which is also closely associated with the Pan African Competitiveness Forum (PACF). According to the record at the ISCP-Uganda Secretariat, more than 50 clusters in a variety of products and services have been launched around the country since 2004 ("ISCP-Uganda Progress Report," 2013). A key challenge is to ensure that these cluster initiatives continue to grow and in a manner that enables them to enjoy a competitive advantage and realize the benefit of clustering.

Clusters are recognized in Uganda's industrial policy of 2008. The policy encourages formation of innovative clusters as a mechanism to enhance sharing of knowledge, coopetition[4], learning, value chain coordination and increased access to markets (Ministry of Tourism Trade and Industry, 2008). By their nature, clusters should thrive on their innovative potential and the value they create in their goods and services.

This paper discusses some of the enabling conditions and barriers to growth of clusters in Uganda, using two case studies: the Bioethanol cluster in Jinja district and the Fruit Processing cluster in Luwero district. A technoscientific innovation systems approach, but with a specific technological innovation system (TIS) analytic framework is used. The TIS has been highlighted, for example, by Bergek et al. (2008) as an analytic framework for understanding the strength and weakness of an innovation system. It is a variant of the concept of innovation systems framed around a technology, product or service (Lundvall et al., 2002; Bergek, Hekkert, & Jacobsson, 2008; Edquist, 2005). An innovation system is an open and evolving relationship among a diverse group of actors involved in the production, diffusion and use of knowledge (Lundvall, 2010; Lundvall et al., 2009).

In applying the TIS analytic framework, the focus is on the product(s) or service (s) around which a cluster is formed. A technoscientific approach is emphasized here in recognition of the way knowledge production is distributed and often situated (Haraway, 2007; Nowotny, Scott, & Gibbons, 2001). The triple helix of university-industry-government relationship (Etzkowitz, 2003) is also considered, as it is the main concept driving the clustering process in Uganda. In this paper, therefore, TIS is seen as creating conditions for the bioethanol production and fruit processing clusters and fostering their innovation processes. Table 3-7 summarizes the TIS framework as proposed by Bergek, Jacobsson, *et al.*, 2008.

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4 "Coopetition" is a term that refers to firms competing and cooperating at the same time (Walley, 2007)

Table 3-7: Functions of technological innovation systems (bioethanol and fruit processing)

Function	Description
1. Knowledge development and diffusion	The breath of scientific, indigenous and local knowledge with respect to fruit processing or bioehtanol production;
2. Influence on the direction of search	Factors which make investment in fruit processing and bioethanol production attractive, including incentives, policy preferences, new markets, etc.
3. Entrepreneurial experimentation	Emerging entrepreneurial activities, for example, new firms venturing into fruit processing and bioethanol production;
4. Market formation	Trends in the development of the market for processed juice and bioethanol, type of the market, potential size of the market, and what is generally driving the formation of this market;
5. Legitimation	General perception about processed juice and bioethanol, and acceptability of these products by the community and other actors.
6. Resource mobilization	Resources that are available, e.g. financial, human, and other complimentary services to support fruit processing and bioethanol production;
7. Development of positive externalities	External economies brought about by the performance in the above functions--political support, advocacy coalitions, etc.

Methods used in the study are described in the following section. Results are presented and discussed in two parts: Part I discusses the Bioethanol cluster, and Part II the Fruit processing cluster. Conclusions and recommendations are presented in the last section.

METHODS

Cluster members (firms) were invited to participate in focus group discussions; one for the Bioethanol cluster in Jinja (eastern Uganda), and the other for the Fruit processing cluster in Luwero (central Uganda). Each group was made up of 10 to 12 participants. Furthermore, three members selected from each cluster were interviewed separately. Academia representatives in the cluster and local government officials in the respective districts were also interviewed. Fruit juice processing was observed in two fruit juice processing firms in Luwero district, and ethanol brewing was observed in five ethanol brewing stations in Jinja district. Each stage of the juice production or ethanol brewing process was explained by production managers, who also addressed all questions and issues put to them. Data from the group discussions and interviews as well as relevant observation notes and pictures were transcribed and analysed in accordance with the technological innovation systems analytic framework presented above.

RESULTS AND DISCUSSIONS

Part 1: The Bioethanol Cluster in Jinja

1.1 Historical Context

The Bioethanol Cluster is located in Kakira near Jinja, about 80 km east of Uganda's capital city, Kampala. The cluster was formed in 2005 with the aim of producing ethanol for automobile and other industrial uses. The ethanol is produced from molasses which is a by-product from sugarcane. The motivation for the cluster is to transform the historical brewing of crude ethanol, locally known as "Waragi", in and around Kakira Sugar Works (KSW), into a modern bioethanol industry, subsequently improving the standard of life of the local community. The name, "Waragi" was coined by indigenous people who could not pronounce "War gin", a term which British colonialists used to describe locally brewed alcohol in Uganda. Waragi production around KSW started in the 1970s after economic collapse under the dictatorial regime of President Idi Amin. When the sugar factory closed, there were no salaries paid to workers. The workers resorted to brewing alcohol as a source of income. This brewing business continued as a fall-back position for people, who retire from or get retrenched from the sugar factory. An estimated 500 people of mixed ethnic origins are directly engaged in Waragi production in and around KSWs. Both women and men are involved in the trade, i.e. in producing and selling ethanol, although women appear to be the majority (about 70%) compared to men.

1.2 Key Actors

Figure 3-15 shows key actors in the Bioethanol cluster. These actors are not necessarily cluster members, but their activities are directly or indirectly connected with cluster activities. In Figure 3-15, it is presupposed that ethanol production progresses when there is financing and human capital available, and enabling governance regimes exist, e.g. policies, laws and regulations. Actors in the Bioethanol cluster can, therefore, be grouped appropriately as those directly supporting or engaged in ethanol production, those financing it, or those supplying the necessary human capital (knowledge and skills). Some of the actors may play single roles (sr), some dual roles (dr), while others may have multiple roles (mr). Local brewers, for example, make alcohol (largely for human consumption), but also use their locally generated funds and savings to finance their operations. Kakira Sugar Works, on the other hand, plays one important single role, that is as a source of molasses. On the other hand, Makerere University plays multiple roles of financing, providing human resource (trained and skilled graduates) and doing value addition to the ethanol production process. As seen in Figure 3-15, actors in the Bioethanol production process are few.

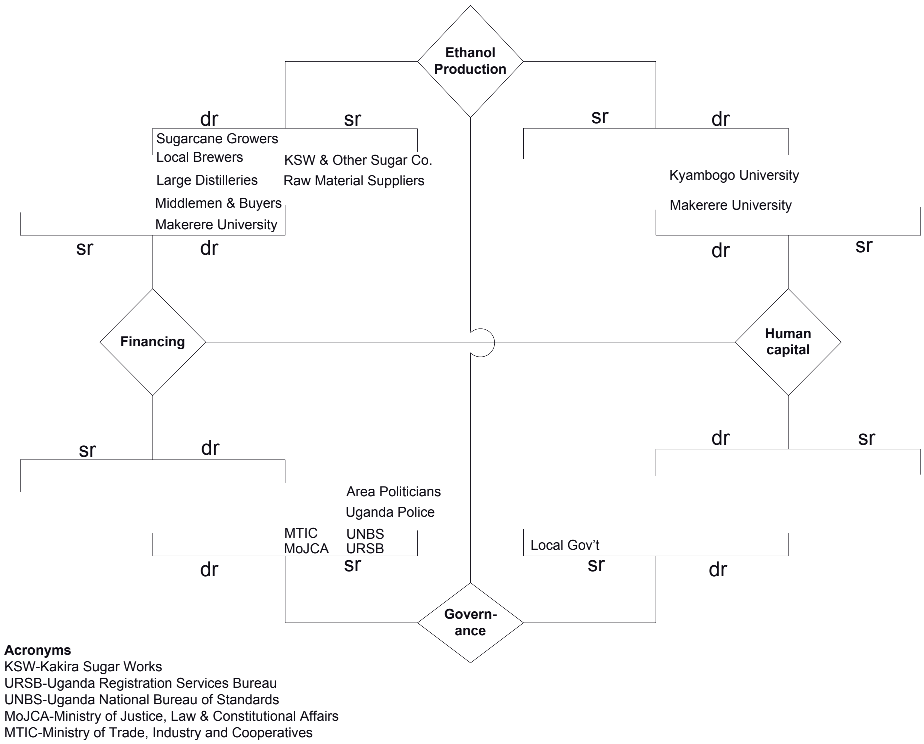

Figure 3-15: Key actors in the bioethanol cluster
Source: Structure adapted from Ecuru, et al., 2012.

1.3 Bioethanol Production in the Cluster

Around 1985, before the sugar factory became operational again, jaggery (crude sugar cane juice) was used as feedstock for making ethanol. Sometimes, the jaggery was boiled to a solid paste (locally known as 'Sukali glue' because it is sticky), and used in this way in ethanol production. Molasses started to be used again, when the factory resumed sugar production in the 1990s. However, for reasons yet unknown, the sugar factory does not sell molasses directly to local brewers. Instead, middlemen buy molasses from the sugar factory and sell some of it to local breweries. Supplies of molasses are brought also from other sugar companies in the region as far as western Kenya and western Uganda.

Brewing is done locally using steel coated metallic drums of 100 litres each arranged in series of three to five, placed over traditional earthen stoves. Firewood is used as fuel for boiling during the distillation process. In order to get 20 litres of ethanol, local brewers mix about 40 litres of molasses with 80 litres of water and 40 litres of vinase, i.e. distillery waste water known by the local brewers as 'Salala'. Vinase is used as a fermentation medium. Ethanol produced by the local brewers is about 40% v/v, much of which is sold for human consumption.

Disposal of leftover vinase or 'Salala' is a big problem for both local brewers and local government. Concentrated vinase with very high chemical oxygen demand and biological oxygen demand could destroy plant life if indiscriminately disposed of in open fields (Chandraju, Thejovathi, & Kumar, 2013). Local brewers believe the vinase could be used as a binder in brick making and house construction, or that some other novel uses of it could be found. In dry season, they spread the vinase along the road to cover dust.

1.4. Functioning of the Cluster

1.4.1 Knowledge Development and Diffusion

Ethanol production follows a fermentation process technology, which has been in use for centuries around the world. The challenge for the Bioethanol cluster is to find more efficient ways of using raw materials (molasses and water) and firewood to get more and higher quality ethanol for possible industrial use. In early 2000, the area Politician learnt about this need and introduced the group to an industrial development not-for-profit organization that was supporting small scale industries in Uganda. The latter organization through a local scientist (chemical engineer) at Kyambogo University trained the local brewers and connected them to the ISCP-Uganda Secretariat at Makerere University. With support from the ISCP-Uganda, the scientist and the local brewers organized themselves and established a cluster to produce high quality bioethanol. This collaboration involved design and testing of a distillation column. The column was designed and fabricated at Kyambogo University and tested jointly with the local brewers at Jinja. The experiment yielded ethanol of between 80-90% v/v. This successfully powered an automobile and a generator. Unfortunately, the success was short-lived (less than a year) as one of the columns got stained (with rust) and the other broke down. Nonetheless the university could continue playing an important role in narrowing this knowledge or technology gap.

1.4.2 Entrepreneurial Experimentation

There are nearly 70 brewing stations, each with approximately five to 10 people. Brewing drums per station vary from one to 10. Each station brews at least once or twice daily. Together, the local brewers produce about 500 litres of ethanol per day. New entrants in brewing alcohol come and go as they get into other businesses. The production of bioethanol did not progress beyond the testing mentioned above. Nevertheless, the local brewers believe that with a properly functioning distillation column, they can organize themselves into a cottage industry, do central distillation, package and sell ethanol for industrial uses. One of the local brewers was quite optimistic, and said,:

> *"…if we could get support and come up with a cottage industry, we would be in a position to buy this Waragi from our distillers and centralise it in one place and purify it, and do packaging, bottling and market it worldwide".*

Jaffe and Azumi (1960) used the term 'cottage industry' referring to economic activities, e.g. a small scale retail business or processing unit, which is carried out on, at, or near the home of the worker or proprietor, and usually run by the proprietor's family members (Jaffe & Azumi, 1960). The dream to establish a cottage industry for bio-ethanol production is alive among cluster members, despite failure of the enterprise to take off. The failure could partly be ascribed to breakdown of the distillation column; but equally important are restrictions imposed by the "Enguli" Act of 1966. "Enguli" is an indigenous word for locally brewed alcohol. The Enguli (Manufacturing and Licensing) Act prohibits the manufacturing, selling, possessing manufacturing equipment, consumption or export of Enguli without a license (see discussion below). To date, however, there are several small and large distilleries producing ethanol, though not connected with the local brewing activity of the Bioethanol Cluster.

1.4.3 Influence on the Direction of Search

The Bioethanol cluster members' aspiration is to produce bio-ethanol for use in automobiles, and other uses such as in manufacture of pharmaceuticals and cosmetics. Their motivation comes partly from the increasing global push to reduce greenhouse gas emissions by developing alternative environmentally friendly renewable fuels. The OECD projects global ethanol production will rise from 100 billion litres in 2011 to nearly 160 billion litres by 2019; and predict that whereas the feedstock for ethanol production will be coarse grains in developed countries, for developing countries it will be root and tubers and molasses (OECD/FAO, 2012). As countries explore green growth strategies, bioethanol production is expected to become more and more important in Uganda and the region. The challenge, however, is though the national energy policy and national sugar policy both recognise biofuels as a potentially renewable energy resource, there is no strategy, incentives and programs yet to translate this into action especially for bioethanol production (Ministry of Trade Industry and Cooperatives (MTIC), 2010). No national standards exist so far for bioethanol. Bioethanol does not feature prominently as one of the energy priorities for Uganda. Therefore, policy incentives to influence investment in and development of the Bioethanol cluster are insufficient.

1.4.4 Market Formation

Most of the ethanol produced by the cluster is consumed as beverage. But with the distillation column functioning well, the cluster has potential to produce ethanol of over 80% v/v for industrial uses provided the market can be secured within the country and abroad. One cluster member said,

> *"If we could come up with ethanol, pure ethanol, ours would be marketable. We did it to the range of 90% v/v. These people (i.e. the potential buyers) would come and buy—the hospitals would buy, it would be used by big hotels, the universities, laboratories and so many others because whatever (i.e. ethanol) is used in Uganda right now comes from outside Uganda."*

However, if a market for bioethanol is to be created, government regulation requiring, for example, blending with fossil fuels, would be necessary. Such a strategy has driven private investments in bioethanol production in USA, Brazil, Europe, China and was also tried in Zimbabwe, Kenya, and Malawi (Shiyan, 2012; Amigun, Musango, & Stafford, 2011). The challenge would then be to establish the necessary capacity within the country to produce sufficient amounts of bioethanol for the automobile industry. The other possibility would be to link the cluster to bigger distilleries who could buy the ethanol produced from the cluster. However, such a strategy would require a proper guiding framework to ensure that the local brewers get fair returns for their efforts. The alternative would be to explore ways of developing the ethanol for use in local stoves, and to create market incentives for this purpose.

1.4.5 Legitimation

Ethanol for industrial purposes is generally acceptable. However, local authorities are concerned about potential for its abuse if not controlled. Some members of the community have negative perception about production of ethanol by this cluster. The cluster members are aware of this but they try to cope with it. One of the cluster members said, *"People enjoy it (the alcohol) but they do not want to be associated with its production"*. Another member said, *"...there is a tendency of citing these Waragi brewers saying they make the environment dirty, and yet it is a business sustaining so many households"*. Some people also view it as an illegal trade. The Enguli Act of 1966 prohibits the manufacture and sale of alcohol without a license. The Act also has provisions to grant exclusive buying license so that other licensed producers only sell to the exclusive licensee. The merit and demerit of this law has been a subject of many years of debate. In their 2004 report the Justice Law and Order Sector established that production and consumption of Enguli is widespread in the country and the product is called different names in different parts of the country. The report recognized that the *"selling of Enguli is a source of revenue especially to the rural poor and some local administrations"* and as a result the Act has outlived its usefulness given also that other big companies are by law authorised to produce a similar product (Ministry of Justice and Constitutional Affairs, 2004). The report recommends decriminalization of Enguli Act. However, in 2010, The Uganda Youth Development Link, a local Non-Governmental Organization published a report calling for strict implementation of the Enguli Act to prevent alcohol abuse and its associated dangers (Uganda Youth Development Link, 2010). The local breweries however, seem to find comfort in the national sugar policy which they believe gives them more leverage to produce ethanol from molasses coming from sugar works. The sugar policy specifically recognises the potential of diversification in use of molasses to make portable alcohol, industrial alcohol and gasohol (MTIC, 2010).

1.4.6 Resource Mobilization

Ethanol production using fermentation techniques is not new. Most of the local brewers are former Sugar Factory workers. The skill of brewing ethanol was learned through apprenticeship within this community. Some members had gained additional skills through training in, for example, entrepreneurship. The local competence base for producing more purified ethanol can be acquired from local universities and associated beer industries in the country. For this particular cluster, the pressing need seems to be more efficient distillation columns and systems for quality control and standardization. This need could be met by working with local universities and research organizations.

With respect to financing, local brewers use their own savings. The local brewers are reluctant to acquire bank loans for their businesses. Red tape (severe conditions for accessing these funds), high interest rates and lack of collateral seemed to be their main concerns/barriers to accessing credit. Nevertheless, local brewers believe they can create more value, if they establish themselves as cottage industry with centralised distillation using more advanced columns. In this way they think they would buy alcohol from individual producers and redistill it to acceptable grades for industrial and other uses.

1.4.7 Development of Positive Externalities

The Jinja district local government is interested in this community of local brewers. The local brewers pay taxes to the local council. To improve their living conditions and waste management, the district plans to acquire land, to which the local brewers would be relocated, hopefully with better amenities. Other than forming themselves into a Bioethanol cluster, there is no presence of advocacy groups or associations that are specifically promoting bioethanol as an alternative form of fuel. Support from civil society and the political elites will be essential for the bioethanol enterprise to grow.

1.5 Summary Conclusions

The Bioethanol cluster in Jinja is isolated with a number of policy, social, and technical challenges. The cluster could benefit from a specific policy effort or strategy and incentives aimed at promoting use of bioethanol for industrial purposes. In the absence of such a strategy and incentives, ethanol production in the cluster may remain for human consumption only, but with social and health ramifications when it is abused, including for example, domestic violence, destruction of family structures, severe and dangerous situations for the children. Therefore, the bioethanol cluster initiative, in trying to transform local ethanol brewing into a modern industrial bioethanol production, should also try to secure practices that minimize risk of alcohol dependency associated with unregulated brewing of ethanol.

Part II The Fruit Processing Cluster in Luwero

2.1 Historical Context

The Luwero Fruit Processing Cluster (LFPC) is located in Luwero district, 65 km north of Kampala City. It was established in 2005. Fruit processing in Luwero started around 1999. The main fruits are pineapple, mangos, passion fruits, papaya, avocado, jackfruit, and tomatoes. These fruits can be found in several other parts of Uganda. The country has a sizeable share of these fruits in east and central Africa (Agona, Nabawanuka, & Kalunda, 2002). The motivation for fruit processing in Luwero is value addition to create jobs for the youth and to diversify household incomes. With this goal, individual local entrepreneurs began their own small fruit processing units in their homes. Fruit processing in the district is characterised by small cottage firms. Nearly 30 micro and small scale fruit processors exist in the district and approximately 70 exist country-wide in the districts of Kampala, Jinja, Lira, Arua and Soroti.

2.2 Key actors

Figure 3-16 shows key actors in the Fruit processing cluster. These actors are not necessarily cluster members, but their activities are directly or indirectly connected with cluster activities. From Figure 3-16, it appears the range of actors exists that can make fruit processing a vibrant and lucrative cluster. A good number of processors supported by organized farmer groups and farmer-centred associations are present. Private sector, government and development partners appear to have provided the necessary financial resources. The supply of skilled personnel in fruit processing seems adequate, and there is also emphasis on entrepreneurial skills, notably by Enterprise Uganda. In terms of governance, the agencies exist such as ministry responsible for agriculture, trade and investments and bureau of standards. Therefore, it appears the necessary actors exist for the fruit processing cluster in Uganda.

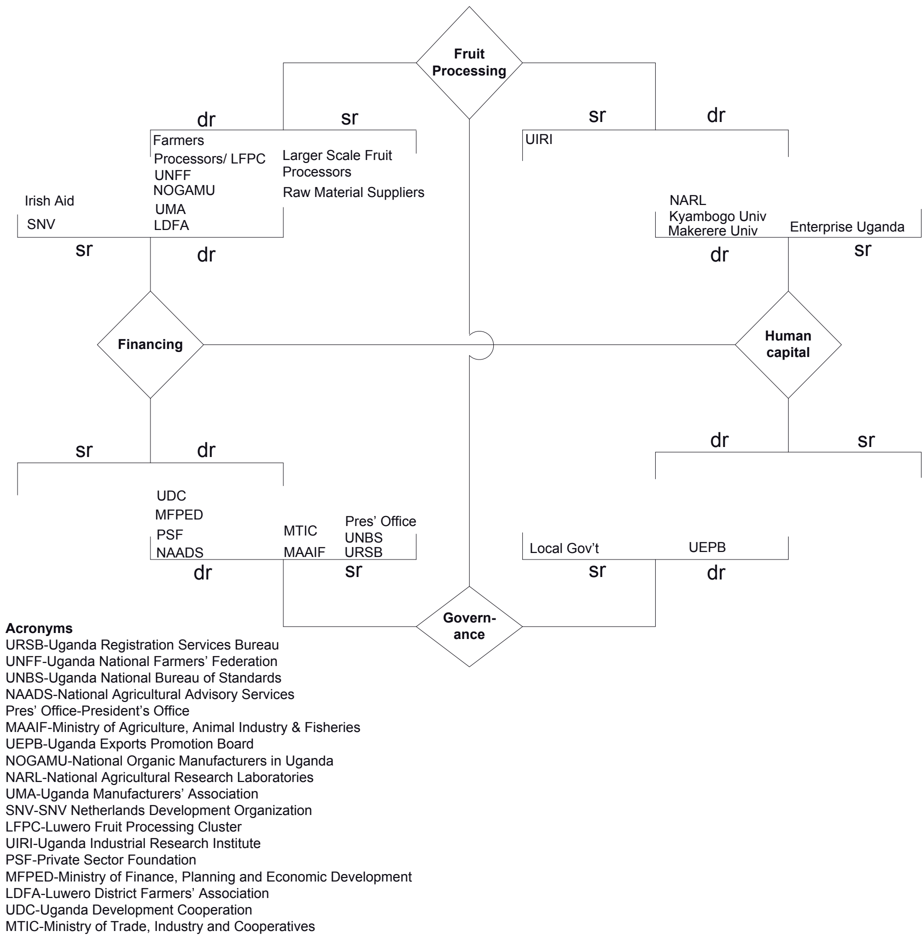

Figure 3-16: Key actors in the fruit processing cluster
Source: Structure adapted from Ecuru, et al., 2012

2.3 Fruit processing by the Cluster

The Cluster produces mainly mixed fruit juices comprised of pineapple, papaya, passion, and oranges. They also produce jam and tomato source. Very basic technology and processing methods are used. The fruits are screened, cleaned with water, crushed and manually squeezed to extract crude juice. The crude juice is then filtered using special nets bought from supermarkets in Kampala. The filtrate (juice) is mixed in certain ratios, and preservatives (sodium benzoate, potassium sorbate, citric acid or sulphur dioxide) and additives (food colour and sugar) added. The juice (mixed) is then pasteurized at 70 – 75 degrees Celsius (for fruits) and 80-87 degrees Celsius (for jam), cooled to about 60 degrees Celsius and packed in glass bottles ready for sale.

The cluster developed plant based preservatives for their juices, which they claim works very well with a reported shelf life of two years. The idea was conceived by one of the cluster members after attending a training workshop organized by a network of indigenous people and researchers in east and central Africa. The cluster then developed the idea further, perfecting it through trial and error until they obtained a formula that seems to work well for them. The cluster has approached the ISCP-Uganda Secretariat at Makerere University for assistance on appropriate ways to protect their intellectual property/knowledge and/or the innovation.

2.4. Functioning of the cluster

2.4.1 Knowledge Development and Diffusion

Juice processing technology is not new. However, for this cluster the main interest is to develop different formulations and to try out juices from a variety of fruits. Some of the cluster members have started using plant based preservatives, which they recounted works as good as or even better than the conventional chemical alternatives. However, the efficacy of these particular plant based preservatives is yet to be ascertained with modern scientific tools. One of the biggest challenges fruit processors face is the high cost of packaging materials. Packaging materials alone accounts for more than half of the production cost. One processor lamented:

> *"Packaging is a problem. It limits our production, because at the end of the day, the production cost goes high; becomes unaffordable and production rate is lowered since you cannot afford packaging materials".*

A 500ml bottle costs about one US dollar. Being small processors, the cluster does not enjoy the economies of scale to make large orders, and orders made take too long to be delivered.

2.4.2 Entrepreneurial Experimentation

The number of fruit processors in Luwero district has increased slightly since 1999. In 2008, the President at the Luwero farmers' request promised to support building of a fruit processing factory in the region. Land for the factory was acquired, but the plan stalled when a prospective investor pulled out of the deal (Kiwanuka, 2010). For the cluster members, it seems that the factory would be of value, if it helped them grow as a cottage industry. One member said emphatically, *"…our strategy is to fight poverty* *through cottage industry so that people can be productive right from their homes"*. Any future investment strategy in fruit processing in this community should weigh opportunity cost of investing in a large scale juice processing factory verses developing a fruit processing cottage industry. Elsewhere in the country, the government in partnership with Korean International Cooperation Association (KOICA) plans to build a citrus fruit processing factory in eastern Uganda (Namirimu, 2012). There are other experimental fruit processing projects at the Uganda Industrial Research Institute, which is processing juice from mango and passion fruits and at the School of Bioengineering, Food and Nutrition at Makerere University, which also houses an incubator for fruit and vegetable products. These developments within the fruit processing sub-sector in the country could enhance profitability of the Luwero Fruit Processing cluster through building stronger synergy among the actors.

2.4.3 Influence on the Direction of Search

Value addition and agro-processing is one of Uganda government's priorities for economic growth and development. Local processors also boast of an organic market for their juices. Although, there is no specific strategy so far for fruit processing at district and national level, it is promoted as one of agro-processing and value addition opportunities. Fruits and horticultural crops are ranked in the Agriculture Sector Development and Investment Plan (DSIP) 2010/11 – 2014/15 as a commodity generally small in size without a significant contribution to the export market, but having a high return on investment and a high potential future impact (Ministry of Agriculture Animal Industry and Fisheries, 2010).

2.4.4 Market Formation

The market for fruits is believed to be growing as people change their dietary habits in preference to fruits and vegetables. The regional market (Kenya and South Sudan) as well as the local market is also believed to be expanding. Luwero's central location makes it a potential fruit hub, serving both local and regional markets. The fruit processors believe that they can have an edge in the organic market. One of them confidently stated, *"for us we use purely fruit juice; that makes us different from the others"*. However, to sustain this unique attribute of the 'Luwero fruits', the processors would have to formally certify their organic fruit claims. They would also have to label their products as organic and possibly register trademarks for the products. But most processors are not aware of trademarks, and how it is acquired or registered. Furthermore, to sustain the fruit market, the production side of it must be supported by breeding systems and good agronomic practices to ensure a steady supply of fruits, and to help maintain a distinction between organic and non-organically produced fruits. This support can come from agricultural extension agents and university partners in the cluster.

2.4.5 Legitimation

Generally, people like fruits, both fresh and processed for different consumption preferences. Parents normally buy processed juice concentrates for their children returning to boarding school. Locally processed fruits juices are also acceptable in hotels and restaurants. Local processors believe their products are well received: *"It depends"*, said one processor. *"Some individuals prefer this (processed juice) others prefer fresh; whereas other families pack it (processed juice) for their children when they are going back to school"*. Another describing the eating habits of customers, said, *"The pineapples you chew live; now you will not be surprised after eating this one, the pineapple, then he asks for his juice: 'Ndetera ku juice wange (translated, "please, bring me my juice')"*. At the table, people drink juice. They also take fruit as desserts. The challenge with locally produced juice is that consumers do not distinguish its price from the one conventionally produced. One processor was disappointed, saying, *"people believe that all these (conventional and organic) juices are the same; so they expect you to sell it at say Uganda Shillings 500, when your bottle alone is Uganda Shillings 2,300… "*. Customers tend to tag the same price on all juices in the market. In the market place it is difficult to convince the consumers to make a judgement on price verses quality. The clusters also have a challenge to secure a quality mark for their products from the Uganda National Bureau of Standards primarily because of costs they would have to incur in remodelling their processing units to meet the Bureaus' requirements. The Bureau has made visits to production premises of the cluster firms and made some recommendations to improve the working premises.

2.4.6 Resource Mobilization

As for fruit processing, there is probably sufficient human resource capacity available in the country based on the supply from science degree programmes at Makerere University, Kyambogo University, Gulu University and Busitema University. In addition, the Uganda Industrial Research Institute, Uganda National Bureau of Standards and the National Agricultural Research Laboratories have specialist capacities to support the fruit processing sub-sector generally and the Luwero Cluster in particular. Other capacities exist in larger more established formal fruit processing industries within the country. What appears to be a problem is the low numbers of value addition programmes targeting fruit processing and possibly low linkages to external market. Consequently, cluster members may not have the opportunity to interact well with other actors in the fruit processing sub-sector.

With respect to financing, there are some challenges with access to credit. There have been initiatives such as the youth entrepreneurship scheme and bank loans, but for the cluster, red tape and high interest rates (not less than 10% per annum) appear to discourage them from getting credit.

2.4.7 Development of positive externalities

The juice processing industry in Uganda is both non formal and formal. But even then there are no organized associations or advocacy groups for locally processed juices. However, the Farmer's Federation appears to be quite strong, although their focus is on productivity and welfare of the farmers. The National Organic Agricultural Movement of Uganda (NOGAMU) could be a useful intermediary body to promote the production and marketing of organic fruit juices.

2.5 Summary Conclusions

The Luwero Fruit Processing Cluster has the potential to grow into a regional fruit hub. However, for this to happen, the Cluster needs to broaden its membership to encompass the multiplicity of actors in the fruit processing subsector. The necessary actors for the fruit processing cluster to grow appear to exist and the functions in fruit processing innovation system can be made stronger by mobilizing the members and catalysing interaction among actors.

CONCLUSION AND RECOMMENDATIONS

The active involvement of academia is paramount in any innovative cluster development effort. The university can fill a knowledge gap and catalyse innovative activity of cluster firms. Initially the university's presence (i.e. Makerere University and Kyambogo University) was felt in both the bioethanol and fruit processing clusters, but its presence waned with time. The distance (more than 50 km) between the clusters and the university is a limiting factor given the weak transport infrastructure and inadequate financial resources. Another problem is little appreciation of limitations of the parties involved in the clustering process. Usually cluster members make demands on their university scientists, which the latter cannot meet. This may bring distrust among cluster members. For example, the bio-ethanol cluster in Jinja expected the university to install and donate to them a distillation column. The fruit processing cluster also expected a juice extractor from the university. While the university can possibly meet these demands, they themselves are constrained by lack of resources to do so. But regardless of the circumstances, the university needs to maintain a significant presence in the cluster community. Establishing a field cohort and engaging in joint projects with the cluster members, including offering incubation support, could be part of the university's long term engagement strategy with clusters.

If the two clusters are to evolve and grow, deliberate policy measures will be necessary to guide and drive innovation and create market opportunities for the bioethanol and fruit processing sub-sectors. Both fruit processing and bioethanol production are potential areas where Uganda can develop value added products and capitalise its green growth strategy. But there appears to be no specific targets and sufficient incentives to drive ambitions and lines of inquiry in product development and innovations within these clusters. Policy measures at the national level are important, but given that these clusters are highly localized and community based, embedding cluster activities in the local government programmes and district development plans can be a good starting point.

Both the bioethanol and fruit processing cluster members seem to prefer a cottage type of industrial growth. They appear to identify much better with cottage industry successes elsewhere, and believe it can be a model for their growth. It means, therefore, that socio-economic and cultural considerations have to be taken into account when planning future investments in the bioethanol production and fruit processing clusters. A cluster development strategy should strike a balance between investing in larger more industrial processing plants and supporting community centred cottages. This notwithstanding, the cluster concept needs to be broadened to include the multiplicity of actors in fruit processing and bioethanol production (See Figure 3-15 and 3-16). More emphasis should be made on delivering products and covering the geographical spread and concentration of the actors involved. This may require cluster facilitators with more convening power; and who can build trust among cluster firms. They should play the intermediary role, which is emphasized in the strategies of cluster development.

Acceptability of the products is absolutely critical for society buy-in and support. Negative public perception about the cluster's activities or products tends to drive away new investments and new entrants. In the case of bioethanol production, for example, policy and legislation to promote industrial uses of ethanol and ethanol as an alternative renewable energy source can help transform the cluster into a modern bioethanol production and processing entity.

For both the bio-ethanol and fruit processing clusters, the role of the community is important in determining the direction and growth of the cluster. Both clusters are community based, and cluster firms are owned by members of the community. Therefore, cluster initiatives in these types of settings should have an active community engagement strategy.

In conclusion, a technoscientific innovation systems approach can be a useful framework for identifying enabling conditions and barriers to cluster development in low resource settings. Socio-economic and cultural considerations become important issues to emphasize in the functional elements.

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3.8. Paper 7

Moving Bio-innovations from Laboratory to Market: Comparing Performance of Four Bio-Innovate Technological Clusters

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ABSTRACT

In this paper a technological innovation systems approach is used to identify and compare strengths and weaknesses of four Bio-Innovate technological clusters and their potential to move bio-innovations from laboratory to market. The four clusters are: i) crop improvement technologies for cassava, sweet potato and potato; ii) value added products of millet and sorghum, iii) biogas and mushroom production from agro-wastes, and iv) industrial enzymes. Data was collected by reviewing relevant national and organizational reports, focus group discussions and key informant interviews with key actors in each technological cluster in Rwanda and Burundi, Ethiopia, Kenya, Tanzania and Uganda. Results show that actors necessary to move bio-innovations to market exist in the region, but they are not interlinked to play complementary roles. Absence of focussed goals, targets and incentives to attract investments in the specific technological clusters seems to be the major barriers. Also, seed distribution systems are underdeveloped and grassroots advocacy groups which play a critical role in technology promotion are weak. A clear bio-economy roadmap by the region's governments, with programs that encourage bioscience enterprise growth and development would assist in addressing these challenges.

Key words: Bioscience, Bio-innovate, Innovation System, Technology, eastern Africa

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2 Stockholm Environment Institute, Sweden
3 National Council for Science and Technology, Kenya
4 University of Dar es Salaam, Tanzania
5 Addis Ababa University, Ethiopia
6 Ministry of Science and Technology, Ethiopia
7 Stockholm Environment Institute, Sweden
8 Tanzania Commission for Science and Technology, Tanzania
9 African Technology Policy Studies Network, Kenya
10 International Livestock Research Institute, Kenya
11 International Service for the Acquisition of Agri-biotech Applications - Africenter, Kenya
12 Ministry of Education, Rwanda

INTRODUCTION

A sustainable and competitive growth pathway for eastern Africa is to develop a bio-economy. The central feature of a bio-economy is using scientific research and knowledge on biological resources not only to produce food and feed but also to develop agro-industrial and value added products like pharmaceuticals, industrial chemicals, and bioenergy (Schmid, Padel, & Levidow, 2012). As the world's demand for agricultural and industrial products increase, attention is turned to the actual and potential role of bio-based innovations as a means to developing a resource efficient and productive economy (Kitchen & Marsden, 2011). Parallel to this, is the growing concern about global climate change and the need to protect ecosystem services. Countries in eastern Africa can use science, technology and innovation (STI) to foster a bio-economy able to meet the region's development challenges.

This paper examines from a technological innovation systems perspective, enabling conditions and barriers to moving bio-innovations from laboratory to market in eastern Africa. The paper is based on a comparison of strengths and weaknesses of four Bio-Innovate[13] technological clusters (see below). Cluster here denotes a grouping of related technologies, innovations or interventions. The Bio-Innovate Programme is actively supporting bioscience innovations on local crops and other bio-resources in eastern Africa through a number of innovation consortia focusing on crops such as cassava, sweet potatoes, sorghum, millet, and beans. The Programme is also assisting African agro-process industries to be more productive and sustainable in converting agro-waste into valuable products such as feed, bio-energy, food and feed products and other valuable by-products and at the same time reduce environmental impacts.

The paper is structured as follows: in section 2.0, the study framework and methods are discussed. In section 3.0, results are presented and discussed, and section 4.0 is conclusion and suggested policy actions to improve conditions for bioscience innovations in eastern Africa.

STUDY FRAMEWORK AND METHODS

Study Framework

Innovation systems can be analyzed using a range of different tools and models (Carlsson, 2002). For this particular work, a Technological Innovation Systems (TIS) framework is used. A TIS can be defined as a network of agents interacting in a specific technological area under a particular institutional infrastructure, e.g. norms and regulations, to generate, diffuse, and utilise technology (Bergek et al., 2008b). The TIS at its heart has a system structure which consists of actors and their networks, institutions and physical artefacts. The system structure helps to enable a number of crucial system processes (or functions) that are necessary for the innovation system to perform (Hekkert et al., 2007). The seven processes used in this study are:

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[13] The Bio-Innovate Programme is hosted by ILRI Nairobi and supported by the Swedish International Development Agency. The Programme is for the period 2010 to 2014.

a) *Knowledge development and diffusion* addresses generation and linking of knowledge connected to the technology/product in question, including research and knowledge of markets and distribution systems.

b) *Market creation* concerns the development of demand for the technology and market niches.

c) *Entrepreneurial activity* concerns the development and testing of market niches and commercialization or dissemination of the technology.

d) *Resource mobilisation* addresses access to financial, human and other resources.

e) *Guidance/policies* concerns the way in which the system is directed in its development, either through strong overarching industry or political visions, policies and strategies.

f) *Getting legitimacy* addresses public acceptance and industry legitimacy for the new technology.

g) *Positive externalities* addresses the external economies brought about by performance of the above functions, including political support, emergence of advocacy coalitions and interest groups.

The structural components of the system, i.e. actors and how they interact is also characterized.

The quantitative scale of 1 to 4 (Table 3-8) developed through a participatory process, summarizes strength of the functions and structural components of each technological cluster as follows:

1=Functions are very poor, sometimes non-existent

2=Functions are poor, but have major weaknesses

3=Functions are fair, but weak

4=Functions are good/getting stronger

Study Design and Methods

For purposes of the study, Bio-Innovate projects were clustered into four distinct but interlinked technological clusters. These were: i) crop improvement technologies for cassava, sweet potato and potato (encompassing use of micro-propagation techniques such as marker assisted selection and tissue culture, to screen and develop disease free planting materials), ii) value added products of millet and sorghum, iii) biogas and mushroom production from agro-wastes (converting agro-wastes for use in mushroom and bio-energy production), and iv) industrial enzymes (focusing on increasing production of three target enzymes: proteases, amylases and xylanases for use in leather processing, textile, and other industries). Each of these clusters consists of a network of organizations, enterprises, and individuals focused on bringing new technologies, products, or processes into economic use.

Data was collected through review of national and regional policy documents and organizational reports, one focus group discussion (8-12 participants) and at least five interviews with key actors in each technological cluster in Rwanda and Burundi (combined), Ethiopia, Kenya, Rwanda, Tanzania and Uganda. A regional meeting was held at which the data from all the countries were analyzed and synthesized.

RESULTS AND DISCUSSION

Structural Components of the Technological Cluster: The Actors

From the results, it appears the actors required to move bio-innovations to market largely exist in the region. That is, there are universities, research organizations, firms, relevant government agencies, non-governmental and civil society organizations which can interact to form functional innovation systems. However, in all the clusters actors are not interlinked to play complimentary roles. For example, with industrial enzymes the few actors involved have no platform for cooperation. Another example, is where specialized actors, supporting specific parts of the innovation system e.g. agro-dealers for nursery inputs in the case of crop improvement technologies, are not involved, making it difficult to establish local nurseries which are vital in scaling up dissemination of clean micro-propagated material. But, as has been seen in the case of micro-propagation of banana in Uganda and Kenya, the number of actors involved and especially new entrants can change the dynamics of an innovation system relatively faster.

Table 3-8: Summary of functions: grades

Bio-Innovate Technology Cluster	**Actors**	**Functions**							**Average**
		Knowledge dev't & diffusion	Entrepreneurial activities	Guidance/ policies	Market creation	Getting legitimacy	Resources	Externalities	
Crop improvement technologies	4	3	2	2	2	3	2	2	2.50
Value added products from millet and sorghum	3	3	2	2	2	3	2	1	2.25
Sustainable utilization of agro-industrial wastes	3	3	2	2	2	3	2	1	2.25
Industrial Enzymes	1	2	2	1	1	3	2	1	1.63

1=Very poor; 4=Good

Knowledge Development and Diffusion

Knowledge development in all the technological clusters is at a relatively high level. The Bio-Innovate Programme has made a contribution in strengthening the knowledge base in all the four technological clusters. In essence, the knowledge base was not a major limiting factor in any of the four technological clusters. This is not to say that there are no gaps. In all the clusters, marketing skills and the ability to make assessment of economic potential of commercialization of technologies and products is still weak. Skills in developing cost effective production and distribution regimes are also weak in the region. However the partners in the innovation consortia who have necessary know-how could link to additional partners in the region and internationally.

A challenge for countries in the region is to maintain and continuously upgrade the knowledge base in the R&D sector. This requires government long term commitment, but also competitive funding opportunities rewarding the formation of new knowledge to strengthen the innovation systems. Maintaining highly trained scientists by giving them competitive remunerations and career opportunities continue to be a challenge in all the six countries in the region. Creating incentives for them to be engaged in innovation activities is a strategic issue that needs to be high up on the region's STI policy agenda.

While public R&D organizations need to be effective in generating and adapting new knowledge and technologies, they are often ill equipped to move research beyond the laboratory. This applies in particular to universities which are structured and organized to train and educate people. Most of them lack solid structures and policies for technology management, such as intellectual property policies and capacities to develop effective contractual agreements, or abilities to link with market actors.

Entrepreneurial Activity

In general, entrepreneurial activities moving R&D knowledge to the market is still a major problem. In the case of micro-propagation of tubers and value addition to millet and sorghum there is an increasing and promising entrepreneurial activity. Breweries and food processing actors seem to be increasingly interested in agro-processing of local crops such as millet and sorghum. But in biogas, mushroom and industrial enzymes production the entrepreneurial activity is still limited.

Given that the private sector in the region is still weak, it is crucial to locate and support entrepreneurial scientists in universities and research organizations who see potential for their innovations going to market. To support such scientists, public organizations need to develop mechanisms and policies where entrepreneurship is rewarded and supported, through for example, business incubation for start-up or spin-off companies. Usually, the scientists are afraid to leave their stable employment in research institutes or universities and take risks in the private sector. Since venture capitalists are almost non-existent in the region, an innovative strategy might be to give entrepreneurial scientists paid leave for a period of two to three years to start up their companies.

Guidance/Policies

In all the countries STI has gained increased attention. As a result, the countries have made significant efforts into developing national STI policy frameworks. However, the STI policies need to be more focused on innovation outcomes. In all the technological clusters, and especially in the case of biogas production and industrial enzymes, the high taxation on imported machinery and processing equipment is a negative factor. In the case of biogas production unclear and poorly defined feed-in tariffs to sell electricity generated from biogas to national electricity grids is also a negative factor. If bioscience innovations are to flow from laboratory to market, governments need to develop policies (with focused goals and targets), incentives and guiding frameworks that clearly benefits specific technological innovations. For example, policies and standards targeted to stimulate local value addition or clean seed utilization or financial incentives for using renewable energy, or industrial enzymes could drive more inquiry into the technological clusters. In general, governments should have a clear bio-economy roadmap.

Market Creation

Markets in all the four technological clusters are weak, but there is a large potential for a functional market to be established. Markets and collaboration with the private sector is a key aspect of the Bio-Innovate programme. However, it seems that few of the Bio-Innovate projects' R&D and innovation agenda were developed in direct response to a clear and articulated market niche.

Market prospects and the ability to sell farm produce for attractive price is crucial. This is seen in the case of micro-propagation of bananas in Uganda and Kenya, where markets for improved and clean cultivars is clearly linked to the market opportunities for bananas. Near the big cities and where the markets are more lucrative, there is a high demand for micro-propagated banana plantlets. The same demand pattern will probably apply for improved cassava, sweet potato and potatoes.

In the case of value addition to sorghum and millet, much remains to be done in establishing a stable market for value added products. This requires investment in marketing campaigns and engaging consumers to receive feedback on products and product development, which are both long term activities requiring substantial resources.

The most important marketing constraints for the production of biogas innovations include lack of coherent marketing strategies to promote biogas production and use, especially by households who may not be aware of the technology or its benefits. Marketing of industrial enzymes are more complex, and will rely heavily on successful pilot case studies and a stable proof of concept. Solid economic evaluation and performance data on specific enzymes and their use may be needed to convince potential users and buyers of the enzymes.

Getting Legitimacy

For all the technological clusters, there is a strong legitimacy for the impact these new technologies and products could have on improving food security, climate change resilience and converting agro-waste for beneficial use in the region. However, in the case of improved micro-propagated material, there were some perceptions associating the products with genetically engineered organisms, and concerns that improved crop varieties lose their natural taste. Public engagement is essential to address these concerns.

Resources

All the four cases experience resource constraints in moving innovations to market. At the moment there appears to be adequate human resources to drive the innovation process forward. An exception is the case of industrial enzymes where there are very few skilled scientists and engineers.

Limited access to funding and steep credit costs is a barrier in all four technological clusters. The funding problem is especially hampering the later stages of the process such as pilot tests, up-scaling, marketing and commercialization. Commercial credits by banks have not yet proven to be a viable option for funding bio-innovation processes in the region. Commercial banks usually prefer to give credits to projects only where there is a considerable investment also by industrial partners. Industrial actors are often only willing, with some exceptions, to co-invest in new bio-based enterprises when the pilot demonstration stage is completed, highly successful and market prospects are promising. In order to successfully move bio-innovations to market, new funding partnerships in which the costs are shared by several parties will be necessary. What is promising is that in some countries e.g. Tanzania, Ethiopia and Kenya, new government-based funding mechanisms for innovation are being developed. Possibly these funding mechanisms can also be targeted to partly fund the later part of the innovation process and assist in bringing products to market. The donor community can play a complimentary role and strengthen government investments.

Positive Externalities

In all the cases, grassroots advocacy, civil society and interests groups specific to the technologies were absent. The exceptional case was that of micro-propagation of clean planting materials, where a Tissue Culture Business Network (TCBN) is active. TCBN is an ASARECA initiative for networking among tissue culture firms at a regional level. Such promotional groups play a critical role in technology promotion and innovation, and should be strengthened.

CONCLUSION

Looking at the four technological clusters and how they perform, a common similarity is that actors and all functions are generally weak (Table 3-8). An exception is in crop improvement technologies cluster which appears to be a more mature field of innovation with fairly stronger functions. A visible pattern, although not very distinctive, is the growing number of actors and improvement in knowledge formation. The Bio-Innovate Programme has most probably been responsible for this improvement. Functions such as entrepreneurial activity, market creation, and guidance need improvement in all the cases.

In conclusion, while advances have been made in collaborative research and product development in all the four Bio-Innovate technological clusters, these have not yet moved to market. The products/technologies have been demonstrated to be viable but their commercialization may not be realized in the limited project time frame.

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PART III

Chapter 4
SUMMARY, CONCLUSIONS AND FUTURE RESEARCH

4.1 Introduction

This sub-section 4.1 links Papers 1 to 7 to the specific thesis' objectives. Each objective is addressed in more than one paper. Interactions among actors in the evolving innovation systems in low resource settings in Uganda (RQ 1) are discussed as well as key policy issues affecting growth of innovation systems in Uganda (RQ 2).

SO 1: Interactions among innovation systems actors

Interactions among actors are the tenet of innovation. Understanding how actors interact and support each other in knowledge production, use and diffusion is essential for innovation policy development. Governments influence interactive processes through policies and support to research and innovation. Such support and commitments from government towards research and innovation are expressed in national development and planning frameworks. In Paper 1, inclusion of science, technology and innovation in Uganda's national development planning process is discussed. The paper notes that elements of science, technology and innovation in the plan should be implemented in the context of a national innovation system where the goal is to strengthen interaction and learning among actors. Patterns of interactions such as joint research projects, consultant and training activities, service provision and informal networks are indicated in Papers 1 to 7. In Paper 2, for example, relationships among actors within the national innovation system are shown. Paper 3 discusses different modes by which formal manufacturing firms interact in knowledge acquisition, product development and innovation. Paper 4 explains interactions among biotechnology actors. In Papers 5 to 7, actors are described in specific sectoral innovation systems, and various ways in which they interact are evaluated. In general, patterns of interaction are diverse and in many instances diffuse and informal and generally weak, especially between firms, universities and public research organizations.

SO 2: Framework/model for analysing innovation systems structure in low resource settings

There is no single framework so far for describing and analysing structure of innovation systems, especially in low resource settings. The various approaches suggested appear more relevant to developed or mature innovation systems in the developed world. Paper 2 discusses an alternative framework, which arguably is suitable for analysing innovation systems structure in low resource settings. The framework can be used at both micro and macro levels. Actors in innovation systems analysed in Papers 5 and 6 were mapped using the framework. In the framework, science, technology and innovation represents dynamic processes including discoveries, inventions, knowledge production, product development, technology dissemination and diffusion of innovations. The supposition is that the processes are possible with sufficient funding, enabling policy regimes, capable human workforce, and actors involved in each functional sphere working interactively and learning from each other.

SO 3: Enabling conditions and barriers to growth of innovation systems in a low resource setting

Building innovation systems arguably is the sustainable growth pathway for Uganda and the region. Innovation systems are evolving in Uganda. The challenge is to locate and support their growth. Enabling conditions and barriers to growth of innovation systems are highlighted in Papers 1 to 4, but more specific ones are discussed in Papers 5 to 7. For example, the absence of specific policies with clear and focussed goals and incentives is a constraint to the growth of innovation systems in Uganda; while the multiplicity of actors present and the changing environment in the university system in favour of entrepreneurship development is an emerging opportunity for building innovation systems in Uganda.

SO 4: Feasibility of using innovation systems approach in low resource settings

Papers 1 to 4 present innovation systems development issues at a macro level; while Papers 5 to 7 considers the issues at a micro level. At the micro level, TIS scheme of analysis is used. As demonstrated in Papers 5 to 7, the strength of TIS can be enhanced by combining with the framework for mapping actors and understanding the structural components of innovation systems introduced and discussed in Paper 2. TIS involves locating actors and understanding how the innovation system is functioning. The framework in Paper 2 helps to do this, in that, first it is used to map actors and determine the structure of an innovation system, and then followed by TIS to examine how good or bad the system is performing. This is diagrammatically represented in Figure 4-1, which is advanced in this thesis as an enhanced TIS framework.

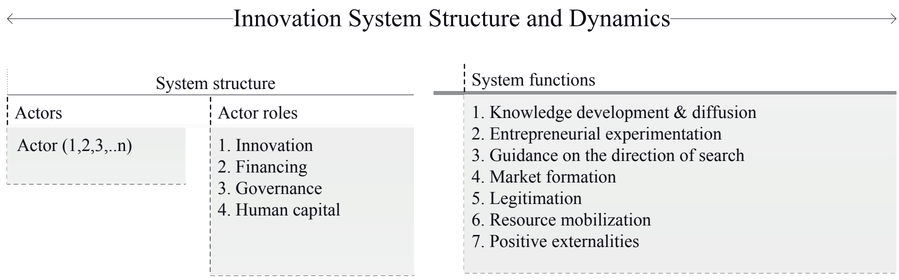

Figure 4-1: Enhanced TIS framework for mapping innovation system structure and dynamics

Furthermore, in using TIS, it was found more appropriate to employ mixed methods (both qualitative and quantitative) in data collection, including, for example, key informant interviews, focus group discussions and meetings, observations and secondary data sources. Therefore, TIS can be used in context specific situations such as the ones discussed above; and in a low resource setting, where it is flexible to recognize and capture unique socio-economic issues in the environment where the technology or product is being produced and/or promoted. This aspect is crucial in gaining legitimacy for the technology or product in question.

4.2 Summary Discussion of the Papers

Paper 1: Integrating Science, Technology and Innovation into National Development Planning:

This paper is premised on the notion that government's commitment to use science, technology and innovation as a driving force for economic growth and sustainable development is normally expressed in its integration of the latter into the national development planning process. The paper explores the extent to which science, technology and innovation is (or is not) integrated into Uganda's national development planning framework.

The push to integrate science, technology and innovation into Uganda's national planning framework began far back in the 1960s. The process was influenced by the UNESCO ministerial conferences on science and technology for the development of Africa until the late 1980s. This together with later efforts by the African Union and its New Partnership for Africa's Development initiative in the 2000s (including the current African Ministerial Conference on Science and Technology which meets regularly), created awareness among political leaders and a few technocrats about the importance of science, technology and innovation in national development. Despite these efforts, however, there were still challenges in ensuring that science, technology and innovation is systematically provided for within the national development planning framework of Uganda. It was not clear how investments were to be made in science, technology and innovation to promote economic growth and development. Moreover, it seemed that capacity of policy makers to design appropriate strategies for using science, technology and innovation to bring about the desired outcomes of economic growth and national development was limited. Mechanisms at national level to engage with local stakeholders on continental or regional science and technology initiatives were also less developed. Therefore, while exogenous influences such as continental or regional initiatives raised awareness of the importance of science, technology and innovation among policy makers and political leaders, they were not sufficient to achieve its integration into the national development planning process.

It was not until 2010 that science, technology and innovation featured vividly in the national development plan of Uganda. The strategic actions for promoting science, technology and innovation outlined in the plan include establishing a ministry of science and technology, implementing affirmative action in schools to promote uptake of science subjects, supporting the teaching of science subjects, promoting value addition, establishing science parks and technology incubation centres, establishing a research fund, promoting research and development and commercialization of research results including managing intellectual property, promoting local artisans, diversifying science and technical courses, and establishing and fostering a national innovation system. These were driven more by endogenous efforts, possibly as a consequence of the awareness created by continental and regional science and technology initiatives. It is also possible that policy makers and the local scientific community had realized by this time that unless science, technology and innovation are explicitly provided for in the national development plan, obtaining budget allocations for it would continue to be difficult. It is important to note though that inclusion of science, technology and innovation in the national development plan 2010/11 – 2014/15 is only a part or a start of a process of integrating it into the national development planning process, and does not always necessarily translate to actions on the ground. The plan itself encompasses many other sectors and priorities which compete for the same resources.

Therefore, real integration of science, technology and innovation into the national planning process can only be evident in the extent to which it is reflected in sectoral implementation plans and strategies. That is to say, when its outcomes are seen through improved quality of education, increased agricultural productivity, improved health care, better and safer transportation, a cleaner environment, more competitive enterprises, etc. It means also that it will be necessary when implementing the science, technology and innovation provisions in the national development plan to recognise the complimentary roles of multiple and diverse actors in the field through an innovation systems approach.

Paper 2: Key Actors and their Relationships in Uganda's Innovation System:

This paper introduces a framework or model for understanding structure and functional elements of an innovation system, especially in a low resource setting. The framework can be applied to innovation systems at all levels, be they national, regional or sectoral. The framework, when used with the understanding that science, technology and innovation is a dynamic process, can to a large extent, conceptually clarify the role of actors in deliberations on investments in science, technology and innovation. It also minimizes generalization of science, technology and innovation to other distinguish-able services such as science education, financing and governance issues. At the same time, the framework avoids narrowly reducing science, technology and innovation to technological artefacts, e.g. machines and equipment. To this end, the framework may possibly help reduce boundary problems, which often arise between dedicated science and technology ministries or agencies and other related service ministries and entities.

Applying the framework to the Ugandan context yielded results (Figure 3-1), which suggests that the necessary actors to support innovation processes in Uganda exist but interaction among them is limited. The university emerges as a significant player in the system. It suffices to say that strengthening universities could be a strategic policy choice to build functional and productive innovation systems in the country. Closer links should, however, be maintained between public research organizations and universities. The type of links between universities and public research organizations can vary depending on the joint programmes, but an example is university lecturers taking up part time positions at research organizations and vice versa. It is more crucial in a low resource setting for both the universities and public research organizations to enhance each other's roles.

Paper 3: Innovation in Formal Manufacturing Firms in Uganda:

This paper explores interactive processes that lead to innovation in formal manufacturing firms in Uganda. Although the results are based on a sample of 71 firms in the subsectors of food and beverages, chemicals and pharmaceuticals, they paint a picture of innovation processes in the manufacturing sector, and highlight areas that need attention.

As the results show, majority of the firms are innovating, but only incrementally, and largely in-house. Universities and public research organizations, which ideally are repositories of knowledge appear not to be actively involved in formal firm innovations in Uganda. While the reasons for this observed phenomenon can be further investigated, it is sometimes argued that incremental innovation can be accomplished using in-house expertise. Therefore, firms may not see the need for involvement of university scientists (Oyeleran-Oyeyinka et al., 1996). However, paradoxically these results show that firms in Uganda work more with people abroad and acquire technologies from abroad, rather than from local universities and research organizations. Also, a significant number of firms invest in human resources training. It could be that research programmes at universities and local research organizations do not address real needs of industry. It may also be that universities and local research organizations engage more with informal than formal firms. Finally, it may be due to inadequate mechanisms in universities and research organizations to disseminate technologies and/or engage with private sector.

Local universities and research organizations as knowledge repositories should strive to be relevant to local manufacturers. Innovative ways of enhancing interaction between universities and public research organizations and local firms can be found in order to realise benefits of a triple helix as university-industry-government co-development. Some of these strategies include having in place good technology management, or as they should preferably be called, business development, policies at universities and research organizations, and tools and practices that build trust among actors.

Paper 4: Biotechnology Development in Uganda:

This paper looks specifically at growth of modern biotechnology as an enterprise in Uganda. There is a growing number of research and development work going on using biotechnology as a tool, especially in crop, fish and livestock improvement, value addition, waste management, and in medicine. As a high end scientific undertaking, modern biotechnology thrives best, where there is a rich pool of knowledge, skills and competencies in basic sciences and engineering. Thus an enabling environment for research and innovation and building capacities in science, mathematics and engineering horizontally are necessary as foundations for vertical growth of a biotechnology enterprise in the country. Actions are needed at a national level such as stable funding mechanisms, enabling policies and high quality education. Actions should also be taken at organizational level such as fostering collaboration among biotechnology research partners, putting in place technology management policies to encourage private sector participation, and ensuring efficiency in procurement and financial management systems. Given the current weakness of private sector in bioscience enterprise development, public sector specifically universities and research organizations have to play greater roles in supporting creation of bioscience businesses and assisting existing ones to be more competitive.

Paper 5: Shea Butter Enterprise in East and Northern Uganda:

This paper highlights prospects of a Shea butter enterprise in Uganda. Shea butter is a unique product geographically indicated in east and northern Uganda. It has a huge yet untapped economic potential, for example, in its use as edible oil, cosmetics and medicine.

Shea butter enterprise is poised to grow if conditions are put in place for actors to cooperate and co-develop. There are scattered efforts trying to promote Shea butter, including emergence of new entrants who have established small cottage Shea butter processing firms. These efforts need to be organized in to a shared vision and strategy to develop Shea butter as an enterprise in the country. The community, for example, is an important actor, whose good will is necessary to preserve the Shea tree. The greatest threat to the Shea industry is cutting of Shea trees for charcoal. This threat can be averted through joint effort with other actors, who can find and deploy alternative energy solutions (e.g. solar energy and biogas) for the community, and hence reduce pressure on Shea trees. Other actors like universities, research organizations and local governments can work together with the community to monitor seasonal variations and advise on good agronomic practices, which enhance fruiting of Shea trees. This will be important for Shea butter processors to have a continuous supply of Shea kernels.

It appears the foundation is already laid, which can support establishment of a formal Shea Butter Cluster as a way to stimulate growth of the enterprise in the region. However, such a cluster if formed should take into account the vast geographic spread of Shea processing zones. Additionally, it will be important to develop and implement a community engagement strategy that targets in an inclusive manner, the multiplicity of actors involved in the Shea butter enterprise. These include for example, women groups, farmers groups, and non-governmental organizations. The local governments, universities and research organizations present in the Shea districts can play an extremely important role in facilitating formation of a Shea Butter Cluster or innovation system. They can also assist in creating enabling conditions for the Shea butter enterprise to thrive, and thereby achieve goals for inclusive growth in the region.

Paper 6: Cluster Development in Low Resource Settings:

This paper identifies enabling conditions and barriers to growth of two clusters in Uganda viz: the Bioethanol and Fruit Processing Clusters. The paper highlights specific issues for each cluster but, which are also relevant for all other clusters in the country. For example, policies and strategies with clear goals, targets and incentives to promote cluster products are necessary. In the case of Bioethanol Cluster, such a strategy might be to promote industrial uses of ethanol; while for the Fruit Processing Cluster, it might be goals to turn Luwero area into a fruit hub for the region. Both central and local government actors can play leading roles in adopting specific policies, goals and incentives to attract investments in the cluster. The university can play a catalytic role in promoting innovations in these clusters, but only if it enhances its presence in the cluster communities. In this respect, it may be worthwhile strategy for Innovation Systems and Clusters Programme Uganda Secretariat to enhance its engagement with other universities in the country on a broader level to be involved in cluster development activities.

A key characteristic of the Bioethanol and Fruit Processing clusters is that both are community oriented, and most cluster firms are informal. Cluster members in this kind of setting tend to favour developing as cottage firms. Nevertheless, the university can make a deliberate effort to assist firms register as companies, and work with them incrementally to get quality marks and trade marks for their products. Such effort requires engagement with more stakeholders and actors, some of whom are identified in the paper.

The long term strategy for the clusters would be to network with all actors and evolve geographically into a wider fruit or bioethanol innovation system in the region and country. In this respect more actors will have to be involved, and the role of dedicated bridging organizations to support the cluster e.g. with business development, market and financial analyses, become extremely important. In this way, business associations or other interest groups come on board as an integral part of the cluster initiative, all with a shared and overarching goal of enhancing competitiveness of cluster products and services.

Paper 7: Moving Bio-Innovations from Laboratory to Market:

This paper identifies and compares strengths and weaknesses of four Bio-Innovate technological clusters in eastern Africa and their potential to move bio-innovations from laboratory to market. Eastern Africa being a bio-resource rich region has great potential to develop bio-based industries. Agriculture is a vital economic activity in region. The region's governments promote value addition to bio-resources and agro-processing. Modern biosciences or more specifically bio-innovations are providing the necessary tools for value addition and agro-processing, which also support modernization of agricultural production and promoting more efficient use of resources.

The required knowledge and innovations can be found in the region's universities and public research organizations. However, translation of this knowledge into goods and services in the market remains a challenge. While actors necessary to move bio-innovations to market exist in the region, conditions that facilitate interactions and learning among them are insufficient. There is need for specific policies and incentives, which attract entrepreneurial scientists to start up bio-based enterprises or at least support existing ones to be more competitive and profitable. Private sector is generally weak in eastern Africa especially in bio-enterprises development; therefore a deliberate effort to build it is necessary. However, scientists often lack entrepreneurial skills. In addition, there is limited experience of starting up science-based enterprises in the region. A lot of new bio-based businesses would need to be incubated. For this reason, setting up or strengthening existing business incubation facilities closely linked to the university is highly desirable to help move bio-innovations to market.

4.3 Overall Conclusions and Policy Recommendations

So far it appears the essential actors who can support and spur research and innovation in Uganda exist, except in a few cases, where for example, venture capital firms and stable innovation financing organizations are missing. The university is emerging as an active player in innovation systems development. In particular, the increasing participation of scientists in entrepreneurial initiatives at the university and some public research organizations is a signal of transformations occurring within the university system, which will enhance its relevance to local businesses and the community. Arguably, the university can be promoted as a locus for research and innovation. The benefit of doing so is illustrated by Etzkowitz and Dzisah (2007) who have postulated that the 'potential for future economic development increases lies within higher educational institutions'. Etzkowitz and Dzisah point to the rich research potential and students at universities as an ever-renewing source of new ideas, and observe that students have a potential to be trained or encouraged to become entrepreneurs. Promoting the university as a hub for research and innovation in Uganda also requires public research organizations to maintain closer links with universities. Such links not only enhance synergies between the two organizational spheres, but also help in concentrating resources available on human capital development (training) and on research and innovation. Furthermore, universities and public research organizations, with support of government, can proactively play greater roles in starting up new enterprises and helping existing ones to be competitive.

This thesis has explicated, though certainly not completely, the dynamics, which characterise innovation systems in low resource settings such as in Uganda. The main actors both at macro and micro levels have been discussed. A formidable challenge is to create conditions that enable actors to interact more and learn from each other. Expanding opportunities for interaction and learning among actors can unlock the potential of innovation systems in Uganda and the region, and make them grow to attain the functionality comparable to stable ones in western economies. In this respect, the role of government becomes critical in ensuring that enabling conditions are in place to foster interaction among actors.

Based on the results and conclusions drawn from this work, the following policy actions are recommended:

i. There is a need to have in place a clear national policy for financing research and innovation. Funding modalities for research and innovation should be streamlined and institutionalized at the national level. The broad policy frameworks for financing research and innovation already exist; but need to be well defined, better articulated and harmonized. For example, establishment of a national research fund is proposed in the national development plan of 2010–2015. The industrialization policy 2008 also proposes establishing a research and development fund for product and process technologies targeting small and medium industries. Furthermore, section 20(3) of the UNCST Act (Cap 209) specifically established a science and technology fund for the purpose of promoting research, although it has not been formally operationalized. These policies should be revisited, and where necessary, new and complimentary innovation policies may be formulated as appropriate. An innovation systems approach should be adopted for their implementation.

   When revisiting the aforementioned research and innovation financing policies, it is preferable to adopt a model, which incorporates dual funding, i.e. where on the one part core funding is provided to universities and research organizations, and on the other, competitive grants awarded annually for research and innovation. The grants should be sufficiently large in size to hire staff, support students training at postgraduate level, and supplement salaries for research scientists involved. It suffices to say that while universities and research organizations continue to receive core funds, the largest proportion of their research and innovation funds should come from competitive grants made available locally and supplemented by funds from abroad. Such an arrangement encourages growth from within. It also ensures that publicly funded research and innovation programmes are subjected to a review and assessment process to enhance quality and promote accountability for results and resources. It does require, however, that the agency administering the funds have clear guidelines and transparent procedures for grants selections and awards, including gender considerations and monitoring and evaluation of outcomes and impacts of projects funded. Such grants should also emphasise synergies between research organizations, private sector and universities by encouraging formation of research groups.

   Competitive grants if well administered can be a powerful tool to determine and address national development priorities. It also ensures productivity for the scientists and innovators and helps to create the necessary synergies and jobs. Furthermore, a competitive grants scheme can support bilateral or multilateral cooperation and joint research and innovation programmes where local counterpart financing is required.

   Funding of research and innovation in a way influences also its governance regime. Whereas there is a no-one-size-fits-all approach to financing research and innovation and governance regimes thereof, two types of competitive grants are necessary in Uganda.

One is financing for scientific innovations with high prospects of increasing productivity and profitability of firms. This type of funding would also support business incubation services for start-up companies. The other is financing research (and innovation) more broadly to close essential knowledge gaps. Three alternative institutional arrangements for the administration of these two types of competitive grants are suggested and discussed as follows:

First, is maintaining the status quo, where UNCST administers the funds as it has done, for example, through the Uganda MSI project. UNCST is the current de facto organization for coordination of research and innovation under the MFPED. UNCST also has other functions including that of research regulation and oversight and science and technology policy development. The challenge is that these functions, including research and innovation fund management, are huge mandates in themselves, which with time would overwhelm UNCST's capacity to effectively deliver on each of them. The functions also potentially conflict under one roof. The status quo can serve well with few programmes, but may become ineffective in the long run with expanding and increasingly diversified and distributed research and innovation programmes in the country.

Second, is co-locating UNCST in a higher Executive Office (e.g. Prime Minister's Office) where it would have direct links to the cabinet council. The composition of UNCST would comprise heads of agencies involved with significant science, technology and innovation activities and other eminent persons appointed on their individual merit as already stipulated in the UNCST Act. This approach views UNCST as a forum and/or platform for engagement on research and innovation policy matters, including priority setting. As such, UNCST would concentrate its efforts on advisory, oversight and coordination functions. In this respect, the financing for scientific innovations with prospects for commercialization and/or industrial application would be handled through an agency preferably under the ministry responsible for trade and industry. Mandates of existing organizations such as Uganda Development Cooperation (UDC) and Uganda Industrial Research Institute can be reviewed to play these roles. UDC, for example, was established by Act of Parliament (Cap 326) in 1952 with a mandate to support and finance creation of or to acquire interest in new business undertakings. This mandate can be expanded to include support for near market scientific innovations through a competitive granting process as well as support for business incubation. Then financing for research and development would be by an agency preferably under the ministry responsible for higher education, assuming that universities become the loci for investment in research and innovation. Such an agency would have to be established. It could take the form of a National Research Council or Foundation as is the case in most research and innovation driven countries e.g. South Africa and South Korea. Heads of these agencies would also be members of UNCST. Research and innovation priorities and budgets for these agencies as well as other sectoral agencies e.g. in agriculture (NARO), health (UNHRO), defence, and energy would be negotiated through the forum or platform provided through UNCST.

Third, is establishing a dedicated ministry for science and technology as already proposed in the National Development Plan, and as approved through a March 2013 motion by Members of Parliament. In this case, the two aforementioned agencies (i.e. one for financing scientific research and the other for near market innovative ideas) would be under the ministry for science and technology. Having a separate ministry for science and technology arguably puts Uganda at par with its neighbours and other countries in the region, which have it viz: Ethiopia, Kenya, South Africa and Tanzania. However, a separate ministry for science and technology would require separate financing for its operations. A separate ministry is also often seen as a competitor with other sister ministries rather than as a unifying and facilitator entity. Additionally, the research and innovation budget appropriated through the ministry for science and technology is most likely to be limited to the agencies under it. This leaves out the other agencies and ministries, which also have significant science, technology and innovation activities, thus limiting interactions.

In trying to figure out an appropriate research and innovation financing and the associated governance regime, critical care should be made to ensure that such regimes enhance interaction among actors in the national innovation system.

ii. Set up business incubation services and locate them at or near universities. Local government authorities or municipal councils should partner with universities in their vicinity to jointly set up and run business incubators. The strategic value of business incubators is that entrepreneurial scientists or other persons with innovative ideas have a place they can go to develop and test their ideas and business models. The incubators should have well defined and publicised selection criteria and curricula including expected graduation time frame for incubatees. Besides, incubatees should have access to venture capital funds for their new businesses. As discussed elsewhere in this thesis, universities and public research organizations in Uganda are seen as knowledge repositories, but the translation of this knowledge into goods and services on the market is a challenge. While collaboration with private sector is necessary and highly encouraged, it is not sufficient to move research products and innovations to market. The private sector in Uganda and the region is still weak, and generally lacks experience in science-based enterprise development. An active business incubation programme can bridge this gap, and be the growth chamber for new businesses. Business incubation has been used successfully elsewhere to nurture start-up companies (Mutambi, 2011). A framework for supervision and support of business incubators should be developed through the ministry responsible for trade and industry.

iii. Initiate institutional reforms in public organizations to make administrative processes less bureaucratic and more efficient. These reforms are necessary for example, in processes involving procurement and financial management, research project approvals (for ethics and safety), technology assessments, contracting and licensing and other registration services. In procurement management, for example, involvement of users (scientists) and experts in the procurement process such as in early preparation of procurement plans, writing specifications, evaluating bids and contract management can minimize delays and reduce risk of procuring wrong equipment or consumables or services or works. Framework contracting (i.e. where suppliers or service providers are contracted to supply certain goods and services for a year or two), especially for consumables, light equipment and regular services could be encouraged. Operations and service delivery can be greatly enhanced through good quality assurance programmes. Therefore, public organizations should be encouraged to establish quality assurance systems or strengthen them where they exist. It is possible to achieve most of the above reforms in a reasonable period by improving work ethics, changing value systems and deploying more use of information and communication technologies through a sustained quality assurance programme.

iv. Develop policies and strategies with clear goals and incentives specially to attract investments in emerging innovation systems. It is evident so far that sectoral and regional innovation systems are emerging in the country. Some of these are discussed in this thesis, viz: Shea butter innovation system, bioethanol innovation system, fruit processing innovation system, innovation systems for crop improvement technologies, agro-wastes transformation and utilization, and others. Nearly all of these innovation systems are constrained by lack of standards, targeted goals and incentives to attract investment in them and drive formation of markets for goods and services they offer. A starting point should be to clearly define these sectoral or regional innovation systems and incorporate them in district or local government development plans as well as in national programmes. Different actors can then find their niches in these innovation systems, and work collectively to achieve a shared overall developmental goal. Bridging organizations such as business associations, innovation-centred non-governmental organizations or agencies with interest in and whose core business is to catalyse transfer of technologies and services should play a critical role in supporting specific innovation policy processes and in gaining legitimacy and clarifying market niches for goods and services an innovation system delivers.

Finally, government's plan to use research and innovation as one of the means to transform Uganda into a middle income country as soon as possible is evident (see for example Uganda's national development plan and Vision 2040). The challenge is to mobilize actors to effectively play their roles in an interactive manner, i.e. to build functional innovation systems. Functional innovation systems can also be the leading vehicle for delivering transformative ideas and innovations to improve living standards. Functional innovation systems can also the vehicle for moving the country and the East African Community along the road to becoming an active player in the global innovation enterprise.

4.4 Scientific Contribution and Originality of the Thesis

This thesis presents empirical use of a technoscientific approach incorporating a specific technological innovation system analytical framework to understand Uganda's evolving innovation systems. An alternative framework for mapping actors and understanding their relationships in an innovation system particularly in a low resource setting has been suggested. The thesis adds to knowledge on application of the concepts of innovation systems, triple helix, mode 2 and technoscience in low resource settings. It further contributes to the ongoing discussions on how research and innovation processes occur and innovation systems evolve in low income countries. The thesis provides an alternative perspective (technoscience and innovation systems) of investment in research and innovation in the country and the region.

4.5 Future Research

Future research should continue to define and locate innovation systems evolving in Uganda and the region. The work should include a prospective (as well as retrospective) evaluation of the effectiveness of interactive and learning patterns of the actors involved. The work should also examine ways of strengthening interactions and learning both within and among actors in the innovation systems. Specifically, more research is needed to understand why some actors interact and others do not in Uganda. Further research will also examine how the framework discussed in Paper 2 (i.e. Figure 3-1) above can be used to measure innovation performance and interactions among actors. For example, indicators need to be developed and or assigned for each functional element, and measured over time. A detailed assessment needs to be made on the kinds of research and innovation activities being carried out in the country in order to guide decisions on priorities for future investments in them.

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